POWER PLANT ENGINEERING

VOL. XXXVI CHICAGO, AUGUST 15, 1932 No. 16

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Published on 1st and 15th of each month, copyright 1932, by the

Technical Publishing Co., 53 West Jackson Blvd., Chicago

New York Office, 171 Madison Avenue

Subscription price: U. S. A. $2 a year; other countries $4 a year. Single copy current issue: U. S. A. 15c, other countries 25c; except January 1st issue U. S. A. 50c, other countries 60c. Single copy back issue: U. S. A. 25c, other countries 35c; except January 1st issue U. S. A. 75c, other countries 85c.

Member, Associated Business Papers, Audit Bureau of Circulations.

Circulation of this issue 23,100

Up a Tree

NO FOOLING! Down in Missouri they know how to use guns, and they use them. When they get a thing treed it's good night!

Those who know Dan G. Pepper, genial superintendent, Board of Public Works, Sikeston, Mo., may feel that he has treed a few kilowatts for the new municipal power system but he hasn't. He's after squirrels this time with the same persistency and success he used last year in going after customers for the new system.

Starting in May, 1931, with no customers, almost 1100 were buying power from the new plant by the end of the year. Two 600-hp. Fairbanks, Morse engine units in a well-designed building supply the power and light the new white way.

Pleasant place for a visit, Sikeston is. If you have an opportunity, visit the city and see the new power system which is making a neat profit. And take a tip from us. Figure on spending some time in Mr. Pepper's office—you'll find it instructive, agreeable and most attractive. We know and have proof.

People all over the country are interested in costs of generating power with Diesels and authorative costs from 10 representative plants are given on page 635.

WITH THE EDITORS

Market for Current

SATURATED MARKET—everybody sold up—not a chance. So might some utility executives argue if told that they could double their domestic load. It may seem so, but how hard have you tried? Domestic load is steady, dependable, year in and year out, all the year demand. Fluctuating, yes. But Tuesday's electric irons balance Monday's washers and oil burners in winter replace the drop in refrigerator load.

Now comes a demonstration of what can be done to that "saturated" market. When the 35,000 Westinghouse employes, just to help make business for the company and work for themselves can sell in a 2-mo. effort $2,600,000 worth of domestic appliances, surely the utility companies can do a comparable job. And they have a continuing goal to work for in the added demand for current to operate the appliances.

A stack of refrigerators 5½ miles high, 25 t. of electric irons, fans to blow a 75-mi. gale through the Holland tunnel under the Hudson make up a sizable job of selling. Incidentally these will use 30 million kw. hr. a year or some $780,000 worth of current, which comes as a gift to the central stations.

This plan was started by the employes but orders were filled through dealers, so the benefit has been widespread from materials producers all the way through to dealers' clerks.

The campaign, managed by H. C. Thomas, was simple. Each employe to sell at least one household appliance during 60 da. And 54,500 sales were closed, 80 per cent of the 68,000 prospects. It is to wonder, what about the other millions of prospects who might be benefited by using electric appliances and help the load curve?

Air Conditioning

ONE OF THE bright spots during the past year is the increasing interest in small air-conditioning units. In the face of most distressing difficulties, equipment of this kind is forging ahead.

There is a reason. The units fill a need as old as civilization and do it in an economical manner quite in line with the popular sales appeal of "1932 prices." Air conditioning has been available for years but at a cost that prohibited widespread application.

Perhaps there was good reason why the small unit was not exploited earlier by the few manufacturers in the field. One suspects that the true reason was that in a comparatively closed field they were skimming the cream off the market with expensive equipment.

Slackening of production in practically every line, sent thousands of small plants and manufacturers scurrying around looking for some lucrative sideline and the small cooling unit field was ripe for the harvest.

All that is needed is a sheet iron can, a fan and a filter. The field is so overcrowded already that cut-throat competition is inevitable and probably no one will make money.

Some of the units are good, some bad. Good or bad, the multiplicity of these units will build up popular demand for air conditioning which cannot be denied. Caught between the cross fire of the exacting industries where air conditioning is already successfully used and the small domestic unit, the industrial middle ground will be forced into line. It behooves all industrial and power engineers to be fully conversant with the movement.

Confidence in Calculating Devices

ENGINEERS in power plants are usually quick to take advantage of mechanical devices that will save physical labor and for this reason it is difficult to account for the resistance often met when trying to encourage more general use of devices that save time in making necessary calculations for plant reports and solving necessary problems that come up in the regular operation of the plant.

Without doubt the most convenient calculating device in use among engineers today is the sliderule but many operating engineers have not taken the trouble to learn how to use it in even the simplest of calculations and many others who have a working knowledge of the sliderule do not trust its accuracy even in calculations based on data obtained with a two-foot rule and spring scales.

No engineer can afford to pass up any scheme that will save time and expense for himself and his employer. The major portion of the calculations which power plant engineers are called upon to do in their operation and maintenance of the plant is of a routine nature, the data and results vary but slightly from day to day. In such cases, tables are sometimes preferred to the use of the sliderule. Some engineers have plotted curves to cover conditions likely to occur in their plant. Another scheme is to design calculating charts for the special conditions encountered. All of these schemes to save time should be considered by the engineer. Unquestionably they can be made to give results as accurate as the original data and they require only a fraction of the time necessary to make the calculation by arithmetic.

Many engineers, it would seem, are confronted with a mental hazard when they attempt to use calculating devices. They may prove to their own satisfaction that the results they secure are within one per cent of those obtained by arithmetical calculation but they consider this hardly sufficiently accurate when dealing with figures. Practically all data used in calculations come from instruments, scales or measuring sticks that are seldom as accurate as calculations made on the ten-inch sliderule and the final results cannot be more accurate than the original data.

To the man who doubts the accuracy of his sliderule or chart calculations only one cure is available—continued checking against arithmetical calculations. More than likely, comparisons of this sort will reveal that fewer serious errors will be made with calculating aids than without them. In time, with practice, accuracy will increase and confidence will be established.

Suggestions for Profitable Reading

Now Everybody's Happy in Dodge City

Kansans are a friendly and sociable people who like company. This admirable though somewhat local characteristic complicated matters when it came to designing the Dodge City power plant. Modern practice of one operator for each thousand kilowatts of capacity, in the case of this 6000-kw. plant, called for a normal crew of about 6 men, two on each 8 hr. shift.

Obviously, this meant one turbine room and one boiler room attendant, an arrangement which in the face of local social precedent was unthinkable. And, of course, imported operators who would work alone were not to be considered in that country where even Bat Masterson had difficulty in maintaining order at the point of a six shooter. No, some other way out would have to be found.

After long deliberation the only way out of the dilemma was to turn the boilers around and remove the curtain wall between the boiler and turbine rooms. This brought the boiler room attendant's rocking chair right up close to the turbine room operator's hammock and now they have no difficulty in carrying on conversation in a normal voice. This arrangement together with automatic combustion control and several other labor saving devices, makes a nice friendly little station of which Kansas can well be proud.

All joking aside, however, this station, though small, has a number of interesting features which should make the article describing its engineering features in this issue well worthy of your attention. Not only were they economical of wall space in the matter of eliminating the curtain wall between the boiler and turbine rooms, but in the boiler room they made the building walls serve as the furnace walls as well. Then there was the matter of the stack—this was built months before the station. Why? Well, read the article, we don't intend to give all our thunder away here. As a matter of fact, we have a suspicion we've said too much already, so we'll pass on to something else.

New Light on Square Corners

Square corners in ducts are better than round corners. "Is that so?" Well! Well! if General Electric says so it must be true—guess we will have to tear out all our old ventilating duct bends and put in square ones."

When the General Electric tests on square corners were made known some years ago, most people took them as gospel truth without close investigation but not Ohio State University. They did some testing on their own hook and found that the velocities used in the G. E. tests were much higher than those used in regular duct work and so they set about investigating the lower velocities.

They found that well rounded elbows are still the best for low velocities, the resistance of the square cornered elbow being 7½ times that of the well rounded elbow. In case a square cornered elbow is necessary, however, because of space requirements, guide vanes of various shapes can be added as explained in the article on this subject by Professor Brown, on page 630. These new results are no reflection upon the accuracy of the General Electric tests but it shows that we must not jump at conclusions.

Suppose You Were Buying a Generator

Suppose you found it necessary to purchase a new generator, an engine driven unit for instance to take care of additional load—no, don't get excited, we're only supposing and it may happen before long—would you know what to ask for? Would you be able to ask intelligent questions and to prepare specifications so that the machine you bought would meet all the requirements as a modern unit of this kind should? If you could you don't need to read any further, but if you are in doubt you should by all means read the article on engine type generators on page 632 of this issue.

This article discusses in detail the design and constructional features of modern engine type generators, both alternating and direct current and it will enable anybody operating or buying such a machine to present a more understanding attitude in regard to them.

Operating Costs Are Only Half the Story

"Many are called but few are chosen" was the theme of the recent Diesel engine investigation by Mr. Charlesworth. As a member of the Iowa Railroad Commission he has access to plant records and costs. He picked out ten representative plants in four states to find out what Diesel power actually costs. Some people have a tendency to forget certain items, he felt, while others have a tendency to exaggerate, so he picked his own and found the mean cost of stations to be about $225 per kv-a. of capacity with the total cost of power ranging from $0.0733 to $0.0182 per kw.-hr.

One significant factor in this investigation as pointed out on page 635, was that in the total cost, the fixed charges are always at least twice the total operating cost and sometimes more. Other interesting facts brought out make this a valuable article to anyone operating or thinking of operating a Diesel plant.

Dodge City, Kansas Has New Station

Famous Frontier City of Cowboy Empire, in Which the Marshall, Bat Masterson, Played Such an Important Role, Has a New Gas and Oil Fired Power Station Built by the Kansas Power Co. With One 6000-kw. Generating Unit and Two 600-hp. Boilers. Ultimate Capacity 25,000 kw.

TO REPLACE a combination steam turbine and Diesel engine station in the center of town and to take care of the growing load in that territory, the Kansas Power Co. 1½ yr. ago planned a new station in the Dodge City (Kan.) district. The old station in congested quarters had reached its ultimate development so the new station was located on the Arkansas River about 3½ mi. from town.

Designed by Sargent & Lundy, Inc., the new station was recently placed in service with an initial capacity of 6000-kw. in one unit. Steam at 425 lb. ga., 750 deg. F. is supplied by two 600-hp. combination gas and oil fired boilers either one capable of carrying full load on the turbine. The stack, breechings and fuel oil storage facilities as now installed are capable of handling the ultimate capacity of the station, 25,000-kw. This additional capacity will probably be, as shown on the plan, one 6000 and one 12,500-kw. unit with one 600 and one 1200-hp. boiler. At present the generator voltage of 13.8 kv. is stepped up to 34.5 kv. although provision is made, as shown by the single line wiring diagram, to step this up to 66 kv. for connection to the 66 kv. line now running northeast from Hutchinson to Topeka and Tecumseh Stations.

In working out the design for the station, it was necessary to keep the investment cost at a minimum and still show a high economy. To accomplish this, new and interesting features were incorporated in the design. The turbine and boiler room are virtually one, with only the crane columns separating this space. The boilers face the turbines so that only two operators are required on a shift and they are in constant touch with each other. The above design materially reduces the building volume from the conventional design.

Another interesting change has been incorporated by using the air cooled walls at the outer sides and at the rear of the boilers as building walls so that the only appreciable section of wall surface in the boiler room is at each end of the firing aisle and at the end of the

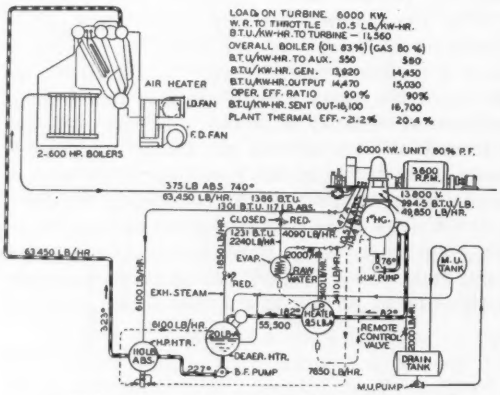


FIG. 1. PERFORMANCE DIAGRAM FOR 6000-KW. LOAD

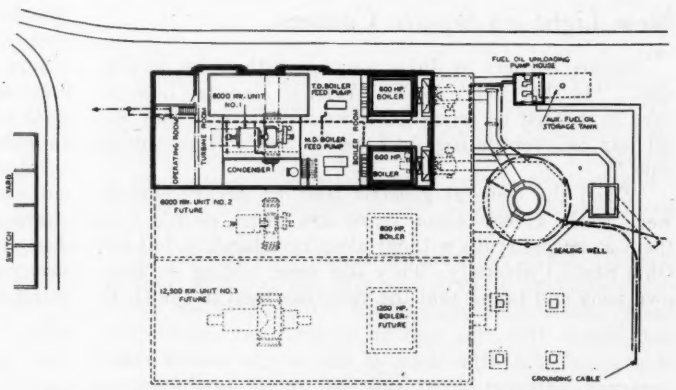


FIG. 2. GENERAL ARRANGEMENT OF THE STATION AND SWITCHYARD

single aisle between the two boilers. This also makes considerable saving in the building volume over the usual design so that the cubic feet per kilowatt of this station is well in line with stations, built along the conventional lines, of 50,000 to 100,000-kw. capacity and the number of employes per thousand kilowatts is also in line with that of larger stations.

The boiler feed pumps, boiler and turbine instruments and control panels are located between the turbine and boilers so that the control of the station can be handled from a central point. The direct connected exciter is totally enclosed and the switchboard, which

rail and unloaded to a 14,850 gal. day storage tank at the unloading pump house or to a 10,000 bbl. storage tank located just south of the elevated water tank. From the small tank the oil is picked up by the burner pumps, heated when necessary and delivered to the combination burners.

Boilers

Each boiler is equipped with five of these burners, in normal operation under control of the automatic combustion control system. Each boiler is a 6000 sq. ft. four drum bent tube type designed for 425 lb. pressure and with a combination superheater designed for 750

FIG. 3. THERE IS NO CURTAIN WALL BETWEEN THE BOILERS AND TURBINE

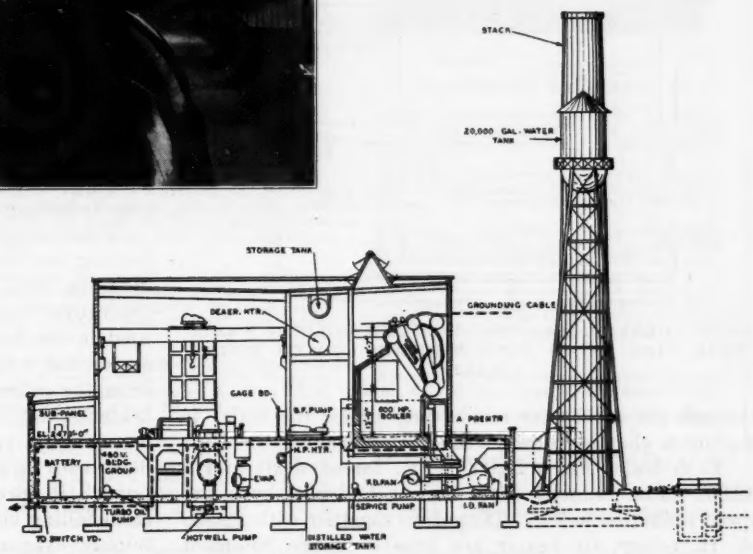


FIG. 4. CROSS SECTION OF THE STATION

is adjacent to the switchyard, has a mimic bus with switch controls duplicating the arrangement in the switchyard. Stack, oil storage tank and equipment grounds are connected to an extensive grounding system consisting of driven pipes and connections to the deepwell pump casings.

Condenser cooling water from three deepwells is pumped through the condenser by the deepwell pumps and discharged to a sealing basin with a weir overflow in the yard. From the weir the waste water flows through a spillway to the Arkansas River. Service water is taken from the condenser discharge and pumped to a 20,000 gal. elevated tank.

Natural gas with a heat content of 1035 B.t.u. per cu. ft. is purchased from the pipe line of the Argus Pipe Line Co. Oil is used for standby. This is received by

deg. F. The maximum steaming capacity is 72,000 lb. per hr. each. Superheaters are made up of 922 sq. ft. of convection surface and 81.5 sq. ft. radiant surface. The latter consists of 2-in. O. D. elements placed on the furnace wall and accessible for replacement through a removable section of the arch.

Furnaces are air cooled with a volume of 5,545 cu. ft. each, and a heat liberation at maximum rating of 16,900 B.t.u. per cu. ft. per hour. Details of construction are shown by Fig. 5. The furnace walls at one side and the back are tied in with the building walls and use the same supporting steelwork. The air cooled spaces are under a positive pressure equal to the forced draft fan discharge pressure. The forced draft fan discharge is split, part passing upward through the back and side walls to the burner in the front, the balance passing

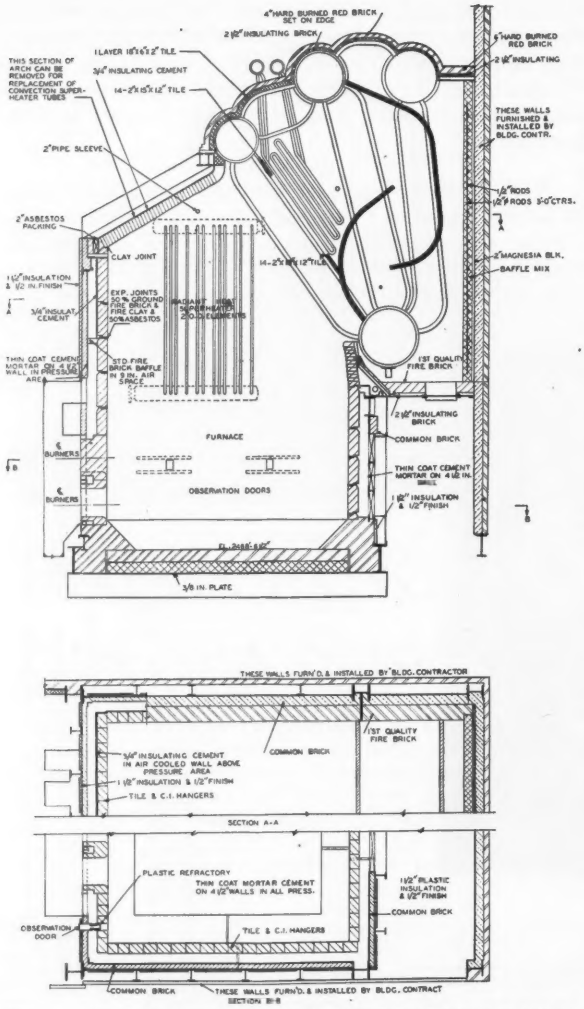

4" HARD BURNED RED BRICK SET ON EDGE
2½" INSULATING BRICK
1 LAYER 18"x6"x2" TILE
¾" INSULATING CEMENT
14-2"x15"x12" TILE
THIS SECTION OF ARCH CAN BE REMOVED FOR REPLACEMENT OF CONNECTION SUPERHEATER TUBES
2" PIPE SLEEVE
2" ASBESTOS PACKING
CLAY JOINT
1½" INSULATION & ½ IN. FINISH
¾" INSULAT. CEMENT
EXP. JOINTS 50% GROUND FIRE BRICK & FIRE CLAY & 50% ASBESTOS
RADIANT TYPE SUPERHEATER 2,000 SQ. FEET
THIN COAT CEMENT MORTAR ON 4½" WALL IN PRESSURE AREA
STD. FIRE BRICK BAFFLE IN 9 IN. AIR SPACE
FURNACE
BURNERS
BURNERS
OBSERVATION DOORS
3/8 IN. PLATE
5" HARD BURNED RED BRICK
2½" INSULATING
THESE WALLS FURNISHED & INSTALLED BY BLDG. CONTR.
⅝" RODS
½" Ø RODS 3'-0" CTRS.
2" MAGNESIA BLK.
BAFFLE MIX
1ST QUALITY FIRE BRICK
2½" INSULATING BRICK
COMMON BRICK
THIN COAT CEMENT MORTAR ON 4½" IN. BRICK
1½" INSULATION & ½" FINISH
THESE WALLS FURN'D. & INSTALLED BY BLDG. CONTRACTOR
¾" INSULATING CEMENT IN AIR COOLED WALL ABOVE PRESSURE AREA
1½" INSULATION & ½" FINISH
TILE & C.I. HANGERS
SECTION A-A
PLASTIC REFRACTORY THIN COAT MORTAR CEMENT ON 4½" WALLS IN ALL PRESS.
1½" PLASTIC INSULATION & ½" FINISH
OBSERVATION DOOR
COMMON BRICK
THESE WALLS FURN'D. & INSTALLED BY BLDG. CONTRACT
SECTION B-B

FIG. 5. DETAILS SHOWING HOW THE BUILDING WALLS WERE TIED IN TO FORM THE AIR COOLED BOILER WALLS

through the air heater and a duct under the boiler to a plenum chamber around the burners.

Each boiler has a 22,000 c.f.m. forced draft and a 42,000 c.f.m. induced draft fan, each driven by a two speed induction motor. These fans together with a 9880 sq. ft. rotary air heater are located in the basement immediately below the rear end of the boiler as shown in the sectional drawing. Boiler feed pumps are on the main floor immediately in front of the boilers. One is a 160 g.p.m., 475 lb., single acting horizontal triplex pump driven through gears at 61.7 r.p.m. by a 1160/580 r.p.m. induction motor. The other is a 175 g.p.m. 475 lb. four stage centrifugal driven at 3300 r.p.m. by a steam turbine taking steam at full header temperature and pressure and exhausting to the direct contact heater.

Boiler and turbine gage boards are located as shown in the plan drawing. The former has, in addition to the combustion control equipment, the drum, boiler feed, oil and gas pressure gages, a 6 point draft gage; steam flow meter and temperature recorders for the flue gas and air from and to the heaters. The latter has pressure gages for the throttle, first, second and third extraction points, gland water and air water pressure; mercury column and barometer and temperature recorder for the steam at the throttle and condensate leaving the hotwell low pressure, deaerating and high pressure heaters. Practically all the valves in the boiler piping have been brought to such a level that they can be operated from the main floor.

Turbine

The turbine is a 6000-kw. unit driving a 13,800 v., 3 ph., 60 cycle generator at 3600 r.p.m. and designed for throttle steam conditions of 360 lb. ga. 740 deg. F. The exciter is direct driven and totally enclosed, being cooled by a small air connection from the generator air cooler discharge, the latter being cooled by service water. Air return from the exciter is filtered to remove copper or carbon particles loosened from the commutator. Cooling water for the condenser is supplied from three 150 ft. deep wells. The turbine pumps with a capacity of 2000 g.p.m. at 65 ft. total head are driven by squirrel cage induction motors.

Three stages of extraction are used for feedwater heating and evaporation as shown by the heat balance diagram, Fig. 1. A low pressure closed heater, open deaerating heater and a high pressure closed heater are used in the feed heating cycle. The single effect evaporator, fed with untreated water, ordinarily takes steam from the intermediate bleed-point and the low pressure heater serves as an evaporator condenser. During low load a cross connection from the high pressure bleed-point with an automatic reducing valve opens and maintains 3 lb. pressure to keep the open heater pressure from falling below that of the atmosphere and for maintaining evaporator capacity even at low loads. This changeover occurs at about 2200-kw. A second reducing valve in the line just preceding the open heater holds

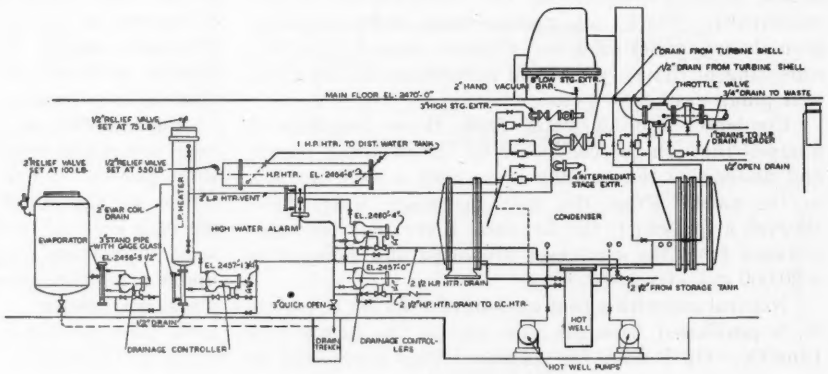


FIG. 6. DIAGRAM OF THE DRAINAGE AND VENT SYSTEM

Principal Equipment—Dodge City Power Station

GENERAL

Owners: The Kansas Power Co.
Location: Dodge City, Kan.
Service: Power and light.
Capacity: Present, 6,000 kw.
Ultimate, 25,000 kw.
Cons. Eng.: Sargent & Lundy, Inc.

BOILER ROOM

Boilers—Foster Wheeler Corp., 2, 6,000 sq. ft., 425 lb. ga., 4 drum bent tube boilers, maximum steaming capacity is 72,000 lb. per hr. Combination super-heater with 922 sq. ft. convection surface and 81.5 sq. ft. of radiant surface to give total steam temperature of 750 deg. F.

Furnaces—M. H. Detrick Co. air-cooled wall type; volume 5,545 cu. ft.; heat liberation at 72,000 lb. per hr., 16,900 B.t.u. per cu. ft.

Air Heaters—Air Preheater Corp., 2, 9,880 sq. ft. rotary type. At 72,000 lb. per hr.; air temperatures, in 100 deg. F., out 518 deg. F.; gas temperature, in 700 deg. F., out 428 deg. F.

Burners—Webster Engineering Co. combination gas and oil. Capacity of each burner, oil fuel, 12,000-lb. per hr., gas fuel, 22,000 cu. ft. per hr.

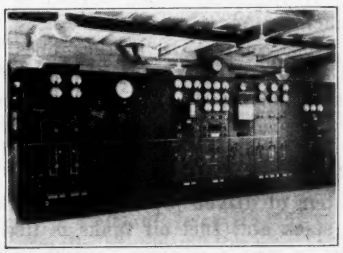
Forced Draft Fans—B. F. Sturtevant Co. 2 Turbovane double width, double inlet, capacity at 1,200 r.p.m. and 100 deg. F. air temperature, 22,000 c.f.m. at 4 in. of water. Driven by 1,200/600 r.p.m. 2 speed squirrel cage induction motors.

Induced Draft Fans—B. F. Sturtevant Co. 2 Turbovane double width, double inlet, capacity at 1,200 r.p.m. and 450 deg. F., flue gas, 5 in. water pressure, 42,000 c.f.m. Driven by 1,200/600 r.p.m. 2-speed squirrel cage induction motors.

Combustion Control—A. W. Cash Co. A solenoid valve on the gas supply line to each boiler is automatically closed when the induced draft fan is slowed below safe speed.

TURBINE ROOM

Turbine—General Electric Co. 1, 3,600 r.p.m. 14-stage, 600 kw. at 80% power factor with 37 kw. 250-v. shunt wound, direct connected, totally enclosed exciter. Gen-



erator voltage 13,800 v., 3-phase, 60-cycle. Throttle pressure 360 lb. ga., total temperature 740 deg. F. Generator connected Y with the neutral grounded through disconnects.

Spare Exciter—General Electric Co. 1, 35 kw. 250 v. compound wound, generator, driven by 50 hp. 440 v. motor.

Generator Air Cooler—General Electric Co. 1, two section with surface 1,625 sq. ft. per section. Air circulation, 16,000 c.f.m.

Oil Coolers—Andale Engineering Co. vertical 2-pass, cooling capacity 25 g.p.m.

Turbine Room Crane—Shepard Niles Corp. 50 t. with 10 t. auxiliary hook.

CONDENSING EQUIPMENT

Condenser—Allis-Chalmers Mfg. Co. horizontal 2-pass surface 7,500 sq. ft., made up of No. 18 Bwg., ¾ in. O.D. arsenical copper tubes rolled at both ends.

Vacuum Pump—Croll-Reynolds Engrg. Co. 1, 2-element, 2-stage steam jet air pump with combined coolers, capacity each section 8.5 c.f.m. at 1 in. abs.

Hot Well Pumps—Allis-Chalmers Mfg. Co. 2, 4 in. 2-stage, 100 g.p.m., 140 ft. head, driven by 1,750 r.p.m. squirrel cage induction motors.

Deep Well Pumps—Layne Western Co. 3, 2,000 g.p.m. at 65 ft. head. Driven by 1,200 r.p.m. squirrel cage induction motors. Pumping from 150 ft. deep 18 in. gravelled wall wells through the condenser to develop an external head 25 ft.

FEEDWATER HEATING EQUIPMENT

Low Pressure Heater—Foster Wheeler Corp. 6-pass vertical U tube, 257 sq. ft. of surface made up of ⅝ in. 18 Bwg. arsenical copper tubes. Capacity 60,000 lb. per hr. from 85 to 182 deg. F.

High Pressure Heater—Foster Wheeler Corp. 4-pass horizontal floating head, 289 sq. ft. surface, made up of ½ in., 16 Bwg. arsenical copper tubes. Capacity 72,000 lb. per hr. from 210 to 322 deg. F.

De-aerating Heater—Cochrane Corporation. Direct contact horizontal with 2-pass vent condenser. Storage capacity 1250 gal., working pressure 20 lb. abs. Heating capacity 140,000 lb. per hour from 187 to 227 deg. F.

Fuel Oil Heaters—Whitlock Coil Pipe Co. 2, four pass, 225 sq. ft. of surface. Heating capacity 36 g.p.m., from 50 to 150 deg. F.

Drainers—Mercon Regulator Co.
Stets Co.

PUMPS

Boiler Feed Pump—Allis Chalmers Mfg. Co., 4x16 in. 3 cylinder horizontal reciprocating pump with capacity of 160 g.p.m. at 61.7 r.p.m. Discharge head 475 lb. Driven by 2 speed 1160/580 r.p.m. squirrel cage induction motor.

Boiler Feed Pump—Worthington Pump & Mach. Corp., 2 in. 4 stage horizontal centrifugal, with capacity 175 g.p.m. against 475 lb. head at 3300 r.p.m. Driven by Terry single stage turbine operating with back pressure of 7 lb. ga.

Service Pumps—Worthington Pump & Mach. Corp., 2, 5 in. single stage with capacity 500 g.p.m. at 120 ft. head. Driven by a squirrel cage 1750 r.p.m. induction motor.

Make-Up Pumps—Worthington Pump & Mach. Corp., 2, Monobloc, single stage, with capacity of 55 g.p.m. at 75 ft. head. Driven by 3425 r.p.m. squirrel cage induction motors.

Oil Unloading Pumps—Viking Pump Co., 2, rotary pumps with capacity of 90 g.p.m. at 390 r.p.m. and discharge head of 55 lb. Driven through gears by 1800 r.p.m. squirrel cage induction motor.

Oil Burner Pumps—Quimby Pump Co., 2, screw pumps with capacity of 36 g.p.m. at 1200 r.p.m. with discharge head of 225 lb. One driven by 1200/600 squirrel cage induction motor, the other by a single stage 1150 r.p.m. Terry turbine.

Heating System Pump—Nash Engineering Co., 1, single stage centrifugal with water capacity of 4 g.p.m. and air capacity of 3 c.f.m. at a discharge head of 10 lb. per sq. in. and vacuum of 20 in. of mercury. Driven by a 3600 r.p.m. repulsion induction motor with vacuum and float control.

Oil Transfer Pump—Viking Pump Co., 1, rotary with a capacity of 10 g.p.m. at 25 lb. per sq. in. pressure. Driven by a 1200 r.p.m. squirrel cage induction motor.

MISCELLANEOUS EQUIPMENT

Piping—Midwest Piping & Supply Co.

Piping Installation—Bass & Linton.

Boiler Feed Water Regulators—Swartwout Co.

Air Compressor—Worthington Pump & Mach. Corp., 1, 8½x9 in. horizontal single acting. Capacity 117 c.f.m. at 100 lb. pressure. Driven at 330 r.p.m. by a squirrel cage induction motor.

Water Tank—Chicago Bridge & Iron Works, 20,000 gal. cylindrical, elevated tank.

Fuel Oil Storage Tank—Leader Iron Works. Capacity 10,000 bbl.

Auxiliary Fuel Oil Tank—Leader Iron Works, 14,850 gal. capacity with 150 sq. ft. of heating coils.

Chimney—A. Custodis Chimney Const. Co., reinforced concrete, 142 ft. high, 10 ft. diam. at top.

Flues & Ducts—Hutchinson Fdry. & Steel Co.

INSTRUMENTS

Instruments
Boiler and turbine room—Consolidated Ashcroft-Hancock Co.
Fluid Meters—Worthington Pump & Machinery Corp.
Draft Gages—Ellison Draft Gauge Co.
Boiler Meters—Bailey Meter Co.
Deepwell Pump Meters—Republic Flow Meter Co.
Gauge Boards—Delta Star Electric Co.

ELECTRICAL EQUIPMENT

Power Transformers—General Electric Co., 3, single phase, 60 cycle OISC, 2000 kv.a. Connected delta-delta 13,800/33,000 v.

Auxiliary Transformers—Wagner Electric Corp., 3, single phase, 60 cycle, OISC, rated 250 kv.a. Connected delta-delta 34,500/460 v.

Lighting Transformers—Wagner Electric Co., 2, single phase, 60 cycle, rated at 25 kv.a. Connected in parallel 115 and 230/460 v.

Oil Circuit Breakers—Westinghouse Elec. & Mfg. Co., 6, type G-11-P TPST, frame mounted, solenoid operated, rated at 600 amp. 34.5 kv.

Potential Transformers—Westinghouse Elec. & Mfg. Co., Type V, 13.8 and 34.5 kv.

Disconnecting Switches—Delta Star Electric Co.

Insulators—Delta Star Electric Co., (O-B Porcelain).

Current Transformers—Westinghouse Elec. & Mfg. Co.

Lightning Arresters—General Electric Co.
Westinghouse Elec. & Mfg. Co.

Fuse Mountings—Delta Star Electric Co.

Fuse Resistors—Schweitzer & Conrad Co.

Potheads—G & W Elec. Specialty Co.

Main Switchboard—Westinghouse Elec. & Mfg. Co., 22 panel, black ebony asbestos, arranged in 2 rows, back to back.

Auxiliary Switch Groups—Westinghouse Elec. & Mfg. Co., 2, 440 v. type CL Air circuit breakers.

Control Battery—USL Battery Corp., 120 cell, 40 amp. 8 hr., 125 v. battery.

Battery Charging Set—Westinghouse Elec. & Mfg. Co., 3½ kw., 140 v. shunt wound.

Clock System—Electric Utilities, Inc. (Telechron).

Cable—General Electric Co.

Motors—Allis-Chalmers Mfg. Co.
General Electric Co.
Westinghouse Elec. & Mfg. Co.

the heater pressure down to 3 lb. at all loads. The heating system for the building is supplied with steam from the intermediate bleed-point. Makeup enters the system through the evaporator, the low stage heater serving also as the vapor condenser for the evaporator.

Electrical

A single line diagram of the station and switchyard is shown by Fig. 7. Future equipment is shown dotted. At present the generator voltage of 13.8 kv. is stepped up to 34.5 kv. by a bank of three single phase transformers, the generator being connected directly to the primary of the transformer, all switching being done on the high tension side. These transformers, rated at 2000 kv-a. were originally purchased for Tecumseh Station and had a 66 kv. winding. They were reconnected and will in the future be equipped with fans attached to the radiators to increase the rating to 2500 kv-a. each.

Eventually the auxiliaries for each unit will be taken from the generator leads of the respective units through a bank of transformers. A reserve source of power will be supplied from the 34.5 kv. bus through a 750 kv-a. bank of transformers to a 460 v. auxiliary transfer bus. With the one unit installed this reserve connection is the one in use as shown in solid lines at the right of the diagram. What will later be the normal connection from the generator leads is shown dotted. The spare exciter is motor driven.

All auxiliaries, with the exception of one boiler feed and one oil pump, are driven by 440 v. motors which, with the exception of the slip ring crane motors, are of the squirrel cage type for full voltage starting. Boiler feed pump, fuel oil burner pumps, induced draft fan and forced draft fans are of the two speed pole changing type. Fractional horsepower motors are of the repulsion induction or induction type.

All squirrel cage motors, except the spare exciter set, are controlled by magnetic switches using push buttons of the maintaining contact type. Magnetic switches for

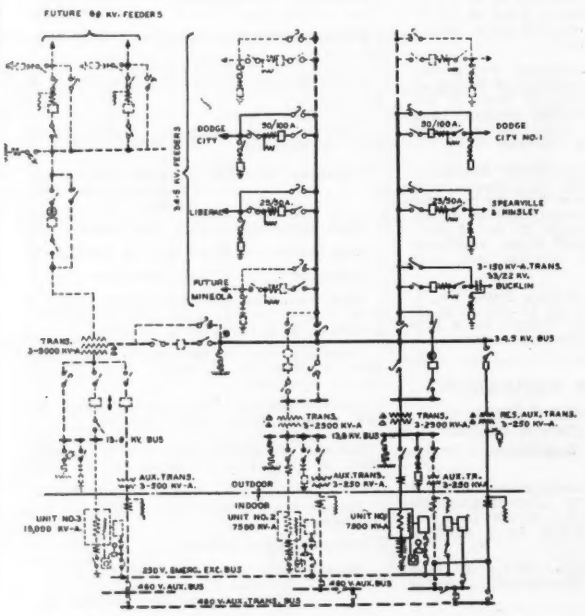


FIG. 7. SINGLE LINE DIAGRAM OF STATION

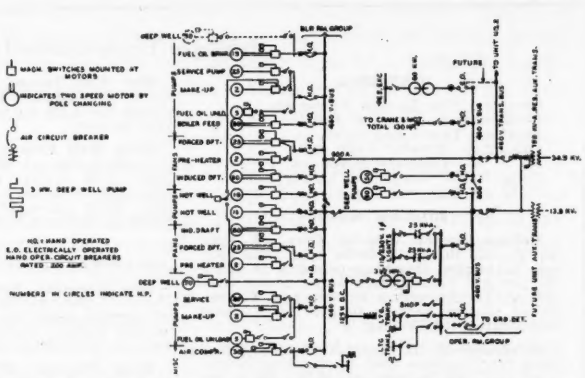


FIG. 8. SINGLE LINE DIAGRAM OF THE AUXILIARY POWER SUPPLY

two-speed motors include pole-changing contactors. All magnetic switches are equipped with ammeter jacks for testing purposes and are located adjacent to the motors. Short circuit protection for magnetic switches is furnished by air circuit breakers at 440 v. switch groups. The spare exciter motor is controlled from the switchboard by an electrically operated air circuit breaker, located in a 440 v. switch group.

Magnetic switches controlling fan motors are interlocked to require the induced draft fan to be started before the forced draft fan motor can be started. Interruption of power to induced fan motors will shut down the forced draft fans. On resumption of power all motors will come back to the original speed unless operators have changed the positions of the push buttons in the meanwhile. An auxiliary system single line diagram is shown by Fig. 8.

The 90 in. main switchboard is of ebony asbestos panels in two rows. It is adjacent to the switchyard and has a mimic bus arrangement which duplicates the switchyard arrangement. As the operator faces the board it bears the same relation to him as does the switchyard itself. Lighting of the yard is by a row of inverted fixtures, on fabricated pipes, around and through the switchyard proper. Power cables are carried out to the yard through fibre conduit but all control cable is of the parkway type buried in the ground. An extensive ground system of driven pipes which includes driven pipes at the stack and fuel oil tanks is tied in with the well casings to give a positive ground of low resistance.

On the basis of one 6000-kw. unit the building volume in cubic feet per kilowatt capacity is: boiler room, 25.7; turbine room, 26.6; switch house, 3.04; office, 1.52; or a total of 56.86 cu. ft. per kw. of capacity.

Bronze welding of a 35-hp. motor frame that was broken by a fall into 37 pieces, involving 55 fractures is an example of the possibilities of reclamation by this process. The bearing housing on the collector-ring end, which took most of the force of the bump, was in 18 pieces; three spiders and part of the rim were broken out of the end bell; the main stator frame ring was in 3 pieces and 6 of the cross members were broken. By careful work, without preheating, fractured edges were beveled, lined up and welded so that, on completion, the rotor was within 0.005 in. of exactly true. Cost of the operation was only 25 per cent of that for a new motor.

Turbine Design Here and in Great Britain

TWO PAPERS PRESENTED BEFORE THE A.S.M.E. REVIEW PRESENT CONDITIONS IN BOTH COUNTRIES

Great Britain

BY F. W. GARDNER, CHIEF ENGINEER
C. A. PARSONS & CO., LTD., ENGLAND

DEVELOPMENTS in turbine practice in Great Britain during recent years have been influenced to a considerable extent by the introduction of the National Electricity Scheme, which provides for the eventual linking up of all the power stations in the country by an interconnecting network of transmission lines known as the "grid." It also provides for the erection and equipment of a number of new large central generating stations, for the extension of the larger and more efficient of the existing stations and for the scrapping of a great number of small and inefficient stations.

At the period of 1920, when the Electricity Commissioners were appointed and given power to investigate the whole subject of electricity supply in Great Britain, the requirements both domestic and commercial were being dealt with by some 540 power stations, varying from quite small outputs up to 100,000 kw. capacity. The largest individual units at that time were about 25,000 kw. Already the number of stations in operation have been reduced to some 300, and provision is made for an eventual reduction to about half that number. A voltage of 132 kv. at 50 cycles has been adopted for the main transmission lines of the grid.

To equip the new central stations, large generating units are required, that is to say, large in comparison with the sizes previously found economical for the conditions existing in England. At the present time a number of units are in operation or under construction ranging in capacity from 50,000 to 75,000 kw. Where extension to existing stations are carried out and where existing plant of non-standard frequency has to be replaced units of from 15,000 to 40,000 kw. capacity are usually required. Practice in England is definitely in favor of single-line units and all the plants now being installed are of this type.

METAL CHARACTERISTICS

Among English engineers there appears to be a definite preference for the 600-lb. level. Much importance is attached to securing the highest possible internal efficiency of each individual part of good overall performance, as it involves less capital expenditure than the adoption of the higher pressure. With the total temperature and other conditions kept the same, the maximum possible saving in fuel at 1200 lb. as compared to 600 lb., amounts to some 5 per cent, but this difference is easily lost unless the efficiency of the boilers, turbines, and auxiliary equipment is fully maintained. Generally accepted steam temperature is 800 to 850 F. at the turbine stop valve.

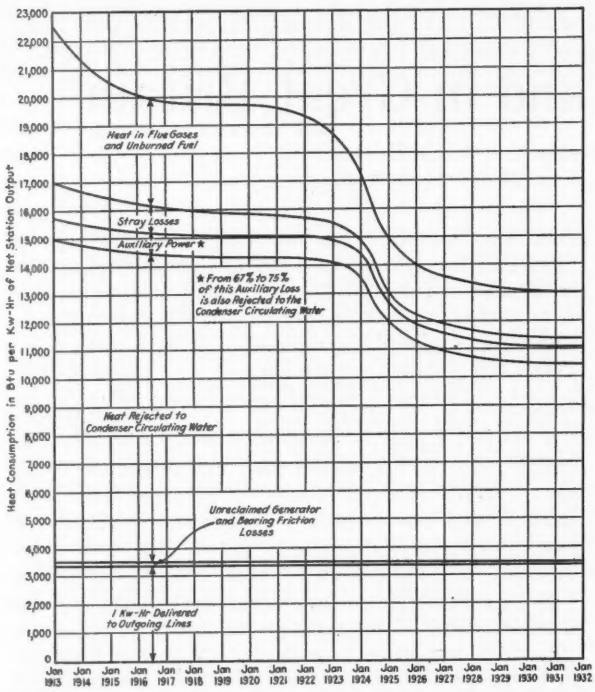
In connection with the problem of service at high temperatures, interest is concentrated primarily on the creep characteristics of the material. It may be broadly stated that for cylinder castings and shaft forgings the stress must not exceed a value which will produce a creep of 10^{-8} in. per in. per hr., a rate which would produce a strain of 0.05 in. in a 5-ft. length in 10 years. For turbine blades that in the high-temperature part are usually of small dimensions and are subjected to their maximum stress only on a small portion of their length, a much higher creep rate is permissible, say, 10^{-6} in. per in. per hr. A similar figure may be taken as applicable to such items as valves, which in any case require readjustment from time to time. Valve stresses are, however, usually quite indeterminate, and design can be based only on experience.

Substantial gain in the steam-cycle efficiency becomes available if intermediate resuperheating, generally called reheating, is adopted. Its merits have not up to the present received the practical recognition of being generally adopted, even for large plants. The earliest reheating installations were put in by the Newcastle upon-Tyne Electric Supply Co. about 1918. In that year a reheater supplied with live steam at a pressure of 275 lb. per sq. in. was put into service on an 11,000-kw. tandem turbine at Carville Power Station. In the following year at Blaydon Burn, a small waste-heat station operated by the same company, a separately fired reheater employing coke-oven gas was set to work and reheated the steam between the cylinders of a two-cylinder geared turbine to 400 F. Owing to the low temperature of the reheat the actual gain in economy in both these installations was small, but the experience gained with them paved the way to the adoption of flue-gas reheaters integral with the boiler in the North Tees "A" Station in 1920, and later in connection with a 40,000-kw. unit at the Barking Station of the County of London Electric Supply Co. The latter was the first installation in which the reheating was carried right up to the initial temperature. The test results on these plants have demonstrated quite convincingly that the full theoretical reductions in turbine heat consumption are realized. Reheating by means of live steam, which at one period became very much favored in the United States, has not received much support in England.

CONDENSERS

A large number of new and revolutionary condenser designs have been introduced during the last few years that seek, first, to improve the steam distribution through the tubes so as to make a greater proportion of the cooling surface effective and, second, to avoid the loss of heat that results from cooling the condensate below the vacuum temperature.

Popularity of the single-flow condenser in America has been the subject of some comment in England, where two-flow condensers have been almost invariably employed. This would, however, seem to be due to a difference of conditions rather than to a radical diver-


Heat Consumption in Btu per Kw-Hr of Net Station Output
Heat in Flue Gases and Unburned Fuel
Stray Losses
Auxiliary Power *
* From 67% to 75% of this Auxiliary Loss is also Rejected to the Condenser Circulating Water
Heat Rejected to Condenser Circulating Water
Unreclaimed Generator and Bearing Friction Losses
1 Kw-Hr Delivered to Outgoing Lines

PERFORMANCE OF TYPICAL STATIONS OF 60,000 KW. CAPACITIES AND HIGHER PLOTTED AGAINST DATES OF INITIAL INSTALLATION

gence of practice. At all events, in the cases which the author has had occasion to consider, the conclusion has always been in favor of the two-flow arrangement. Each type may have several points in its favor and a small difference in conditions may influence the choice between them.

The most unusual practice for tube fixing in large condensers is to expand the tubes at one end and to retain the packed ferrule at the other. Generally, expansion is adopted at the inlet end, as it gives a rather smoother bell-mouthed inlet than the ordinary ferrule. In two-flow condensers, therefore, half the tubes are expanded into one tube plate and half into the other. The practice of expanding the tubes at both ends has not been used in England. The principal argument used against it is the possibility of extensive damage to the condenser should the unit, through some accident, go over to atmosphere. Although such an occurrence may be extremely improbable, the risk of it cannot be altogether ignored, and the use of automatic devices to shut down the machine on a falling vacuum is undesirable, because it may cause an interruption in the continuity of supply.

Use of steel plate instead of cast iron for condenser shells was introduced some ten years ago and soon became generally accepted practice. A riveted construction was at first employed for these steel shells, but more recently riveting has in its turn been replaced by welding, and welded shells are now used for all sizes of condensers.

Great strides made in welding practice and the general tendency to introduce fabricated steel in all branches of power-plant work have led also to the use of steel for water boxes and end doors, particularly for cases where the circulating water is fresh. For salt water it is necessary on account of corrosion to use much thicker plate than otherwise would be required; consequently, the fabricated construction does not possess quite such a definite advantage over the casting.

United States

BY VERN E. ALDEN AND W. H. BALCKE
POWER ENGINEER AND CHIEF POWER ENGINEER
STONE & WEBSTER ENG. CORP.

AMERICAN steam-turbine-plant practice has in the main been dominated by the desire to gain four objectives: Improvement in reliability in order that generating capacity may, to the maximum extent possible, be available for service when needed; reduction in fuel consumption per kilowatt-hour of net station output; reduction in the overall investment per kilowatt of system peak load carried; reduction in cost of operating labor and maintenance.

During the past five years there has been an appreciable amount of sporadic operation of large turbines with steam at temperatures from 750 to 800 deg. F. The limit of good practice was generally considered, however, to be 750 deg. F. at the throttle. Orders were placed in 1929 with three manufacturers for turbines to operate with steam at temperatures from 800 to 850 deg. F. An experimental installation of a 10,000-kw. tandem-compound condensing turbine is now in operation with steam temperatures ranging up to 1000 deg. F. at 390 lb. per sq. in. gage in the Delray No. 3 station.

Raising of the steam temperature to the value of 825 deg. F. makes it possible with a steam pressure of 650 lb. per sq. in. gage and no reheat to limit the moisture in the steam at the exhaust to the reasonable value of approximately 12.5 per cent. This combination, having none of the complications of reheat, is a most attractive one. Edgewater Station and the extension to the Burlington Station are to operate with these steam conditions.

Miscellaneous Developments

Important developments in turbine practice in this country have been the very general use of water-sealed glands with resulting elimination of condensation in the wintertime on the ceiling of the turbine room; the development of speedier governor gear which will prevent the speed of the turbine from rising to a point where the overspeed trip will operate on loss of load by the generator; the almost complete elimination of lateral vibration of turbine wheels as a cause of turbine troubles; the rather extensive use of a vacuum trip attachment on the turbine throttle as a substitute for an atmospheric relief valve on the condenser; and the use of multi-valve construction so as to give good light-load efficiency on the very large turbines.

Condensers

Area of condensing surface has on the average decreased from about 1.6 sq. ft. in 1920 to 0.98 sq. ft. per kw. of turbine capacity installed in 1930 and the amount of condenser circulating water used has decreased from 2.0 g.p.m. to 1.44 g.p.m. per kw. of turbine capacity. For the eight large units operated initially in 1931, an average of 0.71 sq. ft. of condensing area was installed and 1.15 g.p.m. of condensing water circulated per kw. of turbine capacity. The use of single-pass condensers has increased very fast. It has been demonstrated that a 30,000 sq. ft. condenser of modern

design can give the same overall performance as a 50,000 sq. ft. condenser typical of good design practice in 1919, serving a duplicate turbine and supplied with the same amount and quality of circulating water.

From two to eight condensers have been installed to serve each of a number of the large cross-compound and tandem-compound turbines and in a number of cases these condensers have been closely coupled to the turbine exhaust with the condenser tubes placed vertically. The present trend seems to be back to conventional practice with a horizontal condenser placed directly below the turbine exhaust. Ten turbines, ranging in capacity from 105,000 kw. to 165,000 kw., have been installed, each served by one horizontal condenser. Eight of these condensers were designed for a single water pass.

Trend toward the use of single-pass condensers has been an interesting one. Another interesting design trend is that toward the use of tubes rolled into the tube sheets at both ends. This feature reduces leakage and also tends to reduce the investment. A large percentage of all condenser installations in the United States have cast-iron shells and water boxes and brass tube sheets. The pressure to reduce investment has resulted in some of the newer installations being made with welded steel shells and steel tube sheets. It seems probable that this trend will continue at least as relating to the use of welded steel shells.

Station Performance

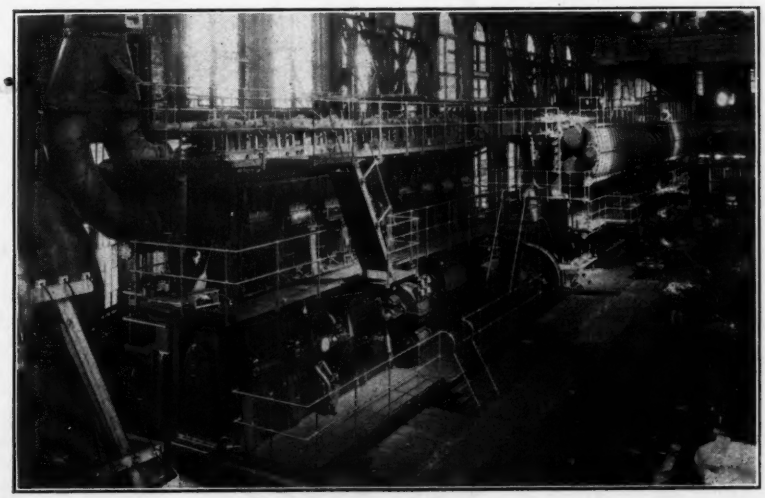
Curves show not the best performance that has been obtained but rather the average performance of typical stations. The following accomplishments are indicative of the performance that is being obtained in the most efficient stations operating at high load factors: The 400 lb. Long Beach No. 3 Station, operating on a station capacity factor of 66 per cent, had an average fuel rate during 1930 of 13,075 B.t.u. per kw-hr. of net send-out; the 1200 lb. Gilbert Station, operating on a load factor of 65 per cent, had an average fuel rate for six months of 12,536 B.t.u. per kw-hr. of net send-out; The Powerton Station, operated at a steam pressure of 600 lb. with reheat during 1931, with an average capacity factor of 63.8 per cent, had an average fuel rate of 12,680 B.t.u. per kw-hr. send-out, this result being accomplished with low-grade coal which averaged 10,213 B.t.u. per lb.; The 1200 lb. Deepwater Station, operating on a load factor of 81.1 per cent during 1931, had an average fuel rate of 12,050 B.t.u. per kw-hr. of net send-out.

A 10,000 kw. mercury-vapor turbine is installed in the South Meadow Station at Hartford, Conn., and two 20,000 kw. mercury-vapor turbines are now being built. One of these turbines will be installed in the Kearny Station and the other in a new power station being built at Schenectady. Operation at the South Meadow Station during the 12-month period from February 4, 1930, to February 4, 1931, was very satisfactory. The indications are that these mercury-vapor turbines, operating together with the steam-turbine plants which absorb the steam from the condensers for the mercury-vapor turbines, will generate energy for somewhat less than 10,000 B.t.u. per kw-hr. of net station send-out.

As yet there has been little indication in American turbine-plant practice of any desire for or real attempt at standardization. The most interesting steps along this line have been the installation by the Detroit Edison Co. of nine duplicate units of 50,000 kw. capacity and the installation of six duplicate units of 40,000 kw. capacity by companies associated with the American Gas & Electric Co.

It would appear that in the years immediately ahead the greatest promise for the reduction in cost of energy on the station bus lies in some measure of standardization, particularly as relating to steam conditions and the operating cycle, and in simplification of design which will result in a substantial reduction in investment.

21,000 hp. in Diesels



SHOP VIEW OF THREE OF THE FIVE 7000 HP. EIGHT CYLINDER, DOUBLE ACTING, TWO CYCLE SOLID INJECTION ENGINES BEING BUILT FOR THE CITY OF VERNON, CAL., BY THE HOOVEN-OWENS-RENTSCHLER CO. AT HAMILTON, O.

Orifice Used to Reduce Fluctuating Pressure

Results of Investigation with Various Sizes of Orifices at Cincinnati General Hospital.

By Anthony A. Fette

AT THE CINCINNATI General Hospital a new laundry was installed the latter part of 1931 at a cost in excess of $125,000. For the live steam supply the plans specified a live steam header as indicated in Fig. 1 with a steam flow meter to measure and record live steam furnished to the laundry, also a reducing valve and other incidentals as shown in Fig. 1.

Steam pressure carried in the power plant is 135 lb. and the laundry was to be furnished with steam at 100 lb. pressure through a 3-in. supply line.

After the laundry was operating some time the steam demand fluctuated considerably and the reducing valve and the flow meter remained right in step with the fluctuations. The appearance of the flow meter recording chart, as shown in Fig. 2, was not satisfactory and it seemed desirable to correct the condition to secure a good flow chart.

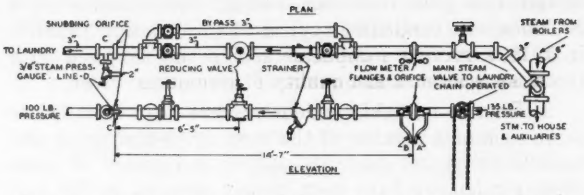


FIG. 1. PIPING ARRANGEMENT FOR LOW PRESSURE STEAM SUPPLY

The flow meter sales representative was called in and applied a manometer to the high and low pressure lines A B (Fig. 1) and it indicated the load was actually fluctuating as shown on chart, Fig. 2.

Then the representative of the reducing valve manufacturer was called in to see if the reducing valve could be made to maintain a more uniform pressure and he contended that the reducing valve was working as it should and maintained a constant pressure regardless of load demands. No remedy was offered by either of them.

Size Determined by Trial

It was then decided, as an experiment, to try a snubbing orifice far enough from the flow meter orifice so that it would not disturb the accuracy of the flow meter and the last flange was selected just ahead of a distribution tee from which a 3-in. line carries on to the south end of the laundry and a 2-in. line to the north end. This flange is 14 ft. 7 in. from the flow meter and 6 ft. 5 in. from the reducing valve.

The maintenance engineer was directed to make an

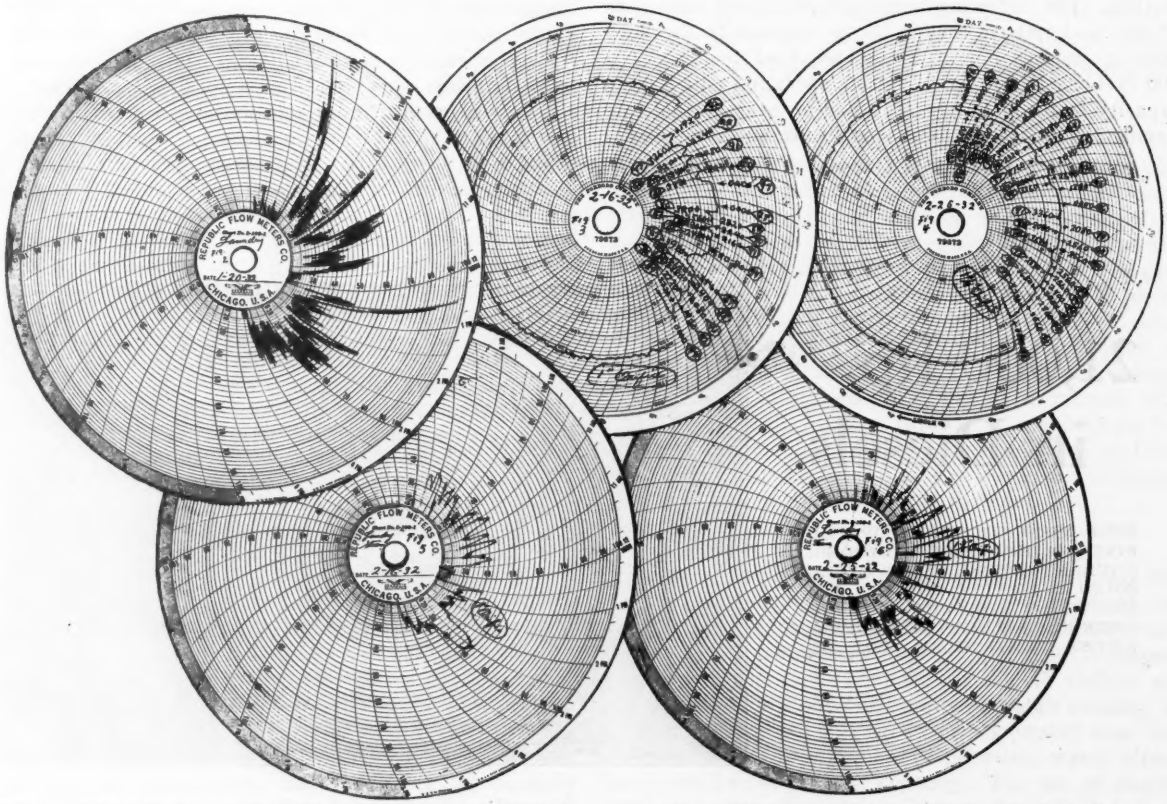


FIG. 2. STEAM FLOW CHART WITHOUT SNUBBING ORIFICE
FIG. 3. PRESSURE CHART WITH 1-IN. ORIFICE
FIG. 4. PRESSURE CHART WITH 1⅜ IN. ORIFICE
FIG. 5. STEAM FLOW CHART WITH 1-IN. ORIFICE
FIG. 6. STEAM FLOW CHART WITH 1⅜-IN. ORIFICE

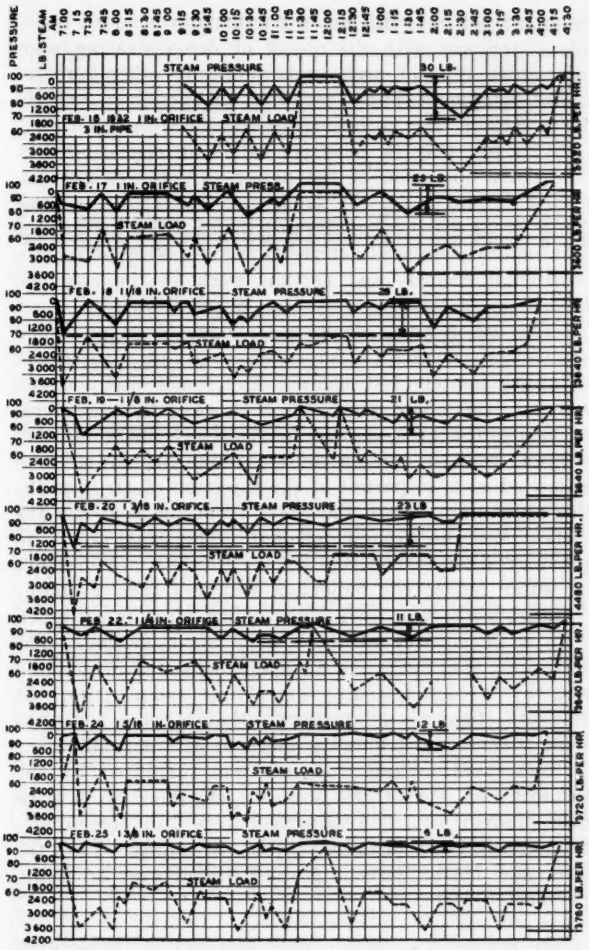

STEAM PRESSURE
30 LB.
FEB. 18 1932 1 IN. ORIFICE STEAM LOAD
3 IN. PIPE
FEB. 17 1 IN. ORIFICE STEAM PRESS.
29 LB.
STEAM LOAD
FEB. 18 1 1/16 IN. ORIFICE STEAM PRESSURE 28 LB.
STEAM LOAD
FEB. 19 — 1 1/16 IN. ORIFICE STEAM PRESSURE 21 LB.
STEAM LOAD
FEB. 20 1 3/16 IN. ORIFICE STEAM PRESSURE 23 LB
STEAM LOAD
FEB. 22 1 1/16 IN. ORIFICE STEAM PRESSURE 11 LB.
STEAM LOAD
FEB. 24 1 3/16 IN. ORIFICE STEAM PRESSURE 12 LB
STEAM LOAD
FEB. 25 1 3/8 IN. ORIFICE STEAM PRESSURE 6 LB.
STEAM LOAD

FIG. 7. PLOTTED RESULTS OF ORIFICE TESTS

orifice from 1/16 in. brass plate with a 1-in. hole drilled in the center, which was inserted between the flanges, Fig. 1. The intention was to start with a 1-in. orifice and increase the size 1/16-in. in diameter after each day's run until the proper results were obtained.

The reducing valve maintained a constant pressure of 96 and 97 lb. and the setting of the valve was not disturbed all through the experiment.

Gages for recording and indicating pressure are connected to ⅜-in. line D, Fig. 1, and after inserting the snubbing orifice at C the reduced pressure records in Figs. 3 and 4 were obtained.

These charts are recording steam pressure charts. This recorder is connected to the main steam header and to secure a record of the laundry test another ¼-in. line was connected from the laundry steam pressure gage line to the recorder and during the daytime this recorder was switched from the header line to the laundry steam line.

Records Obtained

The flow meter records, of which Figs. 5 and 6 are samples, recorded the various load conditions throughout the test. In Fig. 7 the pressure and load conditions are shown graphically plotted on a 15 minute schedule from 7:00 a.m. to 4:30 p.m. (the usual laundry run per day). The results of the investigation are given in the accompanying table and the orifice was left at 1⅜-in. diameter as it produced a satisfactory recording chart with a minimum or negligible drop in pressure which varied only 6 lb. at extreme peak loads.

Figure 5 was the most satisfactory chart but the pressure drop was too great and a compromise had to be reached where the flow meter chart was still satisfactory and with a minimum pressure drop. The flow meter chart, Fig. 6, on Feb. 25 just began to blur slightly but it was a satisfactory improvement over flow meter chart, Fig. 2.

We feel the effort was well repaid in results obtained. Furthermore the experiment has also shown us what amount of steam will pass through various size openings and what pressure drop will result in passing steam through such openings.

Another advantage gained was the removal of the possibility of overbalancing the meter body which happened several times where the load rose over the top of the meter capacity and pushed the mercury in the meter body over on the opposite side. When this occurred the meter body had to be emptied and refilled which would require the time of one of the engineers for several hours, also it spoiled the record for that day.

TABLE GIVING IMPORTANT RESULTS OF INVESTIGATION

Date	Live Steam Consumption, Lb.	Peak Load, Lb.*	Time of Peak Load	Greatest Pres. Drop, Lb.	Pressure Initial	Pressure Final	Diameter of Orifice, In.
Feb. 16	21,000	3920	2:30 p.m.	30	97	67	1
17	20,000	3600	10:30 a.m. & 1:30 p.m.	23	100	77	1
18	20,800	3840	7:00 a.m.	28	97	69	1-1/16
19	20,800	3840	7:30 a.m.	21	97	76	1-1/8
20	17,600	4480	7:15 a.m.	23	97	74	1-3/16
22	20,800	3840	7:15 a.m.	11	97	86	1-1/4
24	21,600	3720	10:30 a.m.	12	97	85	1-5/16
25	20,800	3760	8:00 a.m.	6	96	90	1-3/8

* Highest peak load of the day representing rate of flow per hour

From the table it may be noted that the difference between 3920 and 3600 lb. or 320 lb. steam extra made a difference in pressure drop of 7 lb. The actual pounds per hour pressure drop was 28 lb., from 97 to 69 lb., through 1 1/16 in. orifice.

On Feb. 24 it may be noticed in Fig. 7 that the greatest pressure drop occurred at 2:20 p.m. while the peak load was not as great as at 10:30 but a peak load carried from 1:45 to 2:20 p.m. had caused the pressure to drop about 2 lb. lower than normal.

Award for the big steel pipes to be placed in the four pressure tunnels at Hoover Dam, leading from intake towers to the power plant has been made to Babcock & Wilcox Co. for $10,908,000. The pipes will be so large that they could not be transported by rail, hence must be fabricated on the spot. Diameter will be 30 ft., thickness of walls nearly 3 in. and a section will weigh nearly 150 t. Fifty-foot concrete-lined tunnels have already been built to contain the pipes which will be lowered in sections 1000 ft. from the brink of the canyon. More than a mile of the 30-ft. pipe will be used, the sections being welded or pinned together in the tunnels. Branch pipes to the turbines will be 13 ft. diam. Some 5 yr. will be required to complete the work.

It is estimated that over one billion kilowatt-hours a year can be added to central station load by increased use of household appliances for refrigeration, cooking and heating by adopting promotional rates. If 50 per cent of the possibility is attained, load factor will be increased some 20 per cent.

POWER PLANT ENGINEERING August 15 1932

Power Production with Iowa Coal

LOCAL COALS WITH PROPERLY DESIGNED FURNACE AND SUITABLE EQUIPMENT CAN BE MADE TO GIVE THE LOWEST COST PER THOUSAND POUNDS OF STEAM. BY JOHN M. DRABELLE*

CHANGES IN FURNACE and boiler design have brought above a material improvement in the utilization of fuel after it is received at the power station. These improvements go back to the old fundamentals of combustion, of mixture, air, temperature and time or, in other words, furnace volume sufficient to mix the gases evolved from the fuel bed with the oxygen of the air, with brick work so arranged as to give oxidizing temperatures.

SUMMARY OF BOILER TESTS USING SEVERAL SIZES OF THE SAME COAL

Particulars	Regular 2" Screenings	Prepared 2"x 1/8"	Crushed 2"	Prepared 1¼"x 1/8"
Number of Days of Test	10	5	5	5
Average Results				
Pounds of Coal Burned	99,442	99,641	96,490	99,705
Water Fed to Boilers Lbs.	664,300	674,000	654,000	668,600
Blow Down Water Lbs.	8,673	9,039	9,156	4,202
Water Evaporated	655,627	664,960	644,844	664,398
Boiler Rating %	170	170	170	170
Boiler Feed Temperature	216	214	214	216
Steam Pressure Lbs.	221	222.5	219	219
Steam Temperature ° F.	567	570	565	565
Super Heat ° F.			170	
Water Evaporated/Lb. Coal	6.60	6.67	6.67	6.60
% C O_2 in Flue Gas	11.7	12.20	14.18	12.40
% O_2 " " "	7.3	6.50	3.86	6.60
Lbs. Coal Burned/Sq.Ft./Hr.	32.9	33.18	32.12	33.18
Screenings Test				
% Held on 1.5" Screen	2.33	1.93	3.84	00.00
" " " .742 "	26.38	32.21	31.14	7.99
" " " .371 "	23.51	23.00	22.63	23.81
" " " .185 "	17.03	16.48	15.27	23.66
" " " .093 "	10.21	9.81	9.04	15.94
" " " .046 "	7.29	6.43	6.46	13.04
" Thru to Pan	13.26	10.10	11.65	17.33
Total	100.00	99.96	100.03	100.00
Coal Analysis				
B. T. U. as Received	9,325	9,470	9,910	9,197
Ash " "	18.28	17.84	13.60	19.74
Sulphur " "	4.05	4.42	4.42	4.01
Moisture " "	14.62	13.68	14.71	14.18
B. T. U. Dry Basis	10,924	10,970	11,625	10,349
Ash " "	21.40	20.67	15.44	25.16
Sulphur " "	4.75	5.12	4.98	4.99
B. T. U. of .046 Material	10,583	10,621	11,649	10,349
Ash " .046 "	23.09	22.32	15.79	25.16
Sulphur " .046 "	4.73	4.90	5.12	4.99
B. T. U. of Fines in Pan	9,653	9,580	10,747	9,611
Ash " " " "	29.08	29.92	15.81	29.66
Sulphur " " " "	4.83	5.08	5.12	5.19

One of the big advances in the securing of higher boiler and furnace efficiency has been the air pre-heater delivering air for combustion at a temperature of from 350 to 400 deg. F. The improvement in combustion process is not at present thoroughly understood but it can best be described as giving a more snappy combustion. Of course, there is an actual heat saving, due to the return of heat thus reclaimed from the flue gases going to the stack into the atmosphere.

The man operating a horizontal return boiler is interested in the efficiency that would be obtained on his particular boiler and not what might be obtained on some extra large boiler in some other boiler plant operated under highly skilled supervision with all of the modern equipment such as air pre-heaters and water walls, etc. Data which is presented in this paper is the work of the Iowa Railway & Light Corp. at its Marshalltown, Ia., power station, where a series of tests have been carried out with not a particularly modern boiler plant and not with the object of demonstrating some particular type of arch, stoker, or any other form of boiler equipment, but to see what was possible to obtain from day to day as operating results with Iowa fuel.

This test may be properly called an operating test. The daily operation of the power station was not disturbed in any way, the same men operated the same boiler from the start of the test to the finish. The only sign of any increased activity was the taking of certain additional records and certain work in the chemical laboratory of the corporation at Marshalltown.

The boiler was a 4850 sq.-ft. Edge Moor, equipped with a Superheater Co. superheater, giving a superheat of approximately 150 deg. F. The stoker was a Green natural draft chain grate; the arch was a modified form of suspended arch, having a relatively short ignition section, then a curtain wall through which air was admitted so as to permit of the injection of air over the fire at a point where the gases from the coal are the richest and the oxygen deficient. The draft was supplied by a 200-ft. concrete stack. For the measurement of water fed to the boilers, a Builders Iron Foundry Venturi meter was used. The boiler plant is equipped with a Permutit continuous blow down system. The feedwater was heated in an open feedwater heater and also by a closed heater extracting steam from the eleventh stage of the turbine. Boilers were equipped with Diamond soot blowers operated at 8-hr. intervals.

Coal used during this test was furnished by the Scandia Coal Co. of Des Moines from their No. 4 mine near Madrid, Ia. The sizes used were 2 in. screenings; 2 in. crushed run of mine; 1¼ in. screenings. Both the 2-in. and 1½-in. screenings had passed over an ⅛-in. perforated plate.

*Iowa Railway & Light Corp., Cedar Rapids, Ia. From a paper delivered before the Iowa Section of the N. A. P. E.

AS A RESULT of recent developments in the forging of monel metal rods, shafts and spindles, in large diameters at the plant of The International Nickel Co. at Huntington, W. Va., it has been possible to further increase the range of physical properties of such materials. Engineers are now able to secure a uniform yield point in excess of 70,000 lb. per sq. in. with an ultimate tensile strength over 90,000 lb. per sq. in. on forged bars from 3 to 6 in. in diameter. Elongation value averages higher than 25 per cent. One of the first large forgings to show these properties was a propeller shaft 6 in. in diameter and 14 ft. long. The finished shaft which weighed 1534 lb. was forged from an 18 in. square milled and chipped ingot weighing 6940 lb. This ingot was forged to a rod 6⅝ in. in diameter and then machined to 6 in. diameter. Its physical properties, as shown by a longitudinal test piece taken midway between the center and surface, were: 77,000 lb. per sq. in. yield point; 101,000 lb. per sq. in., ultimate breaking strength; 30.5 per cent, elongation in 2 in. and 62.1 per cent reduction of area. A transverse test made from samples taken midway between center and surface indicated a yield point of 73,750 lb. per sq. in., ultimate breaking strength of 103,000 lb. per sq. in., with an elongation of 25.5 per cent in 2 in. and a reduction of area of 40.3 per cent.

TOO SMALL a discharge pipe from a trap may limit the flow of condensate and slow down the production of cookers or steam kettles.

Power Utilization

Operation Charts

Work your formulas into graphs and save time in calculating reports

By George P. Pearce

HARDLY anything will save more time and give better results around a plant than a set of home made charts designed to fit the conditions found there. I know many cases where men who have to turn information into the office for cost keeping purposes spend an hour or so every day figuring out the results from their readings. In most of these cases, had they but taken the trouble to make some simple charts, they could read their answers straight off these in a few seconds.

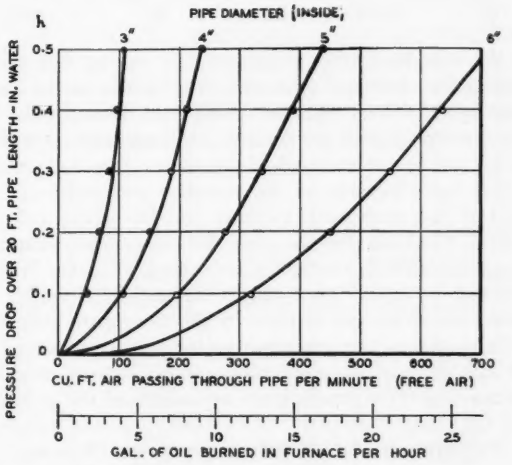
Perhaps the best way to show the advantages of special charts is to take an actual case that recently came up in a large plant. At this plant were a lot of oil furnaces for which the cost keeping department was anxious to know the amount of air and oil used on various jobs. No instruments or meters were available and the best that was being done was to mark the setting of the oil valve, then, after the furnace was shut down, to disconnect the union at the oil burner, open the valve to the mark and check the time it took for one gallon of oil to run out. In a rough and ready way, this gave fair results, the amount of air used being calculated from the oil consumption on the ratio of 1560 cu. ft. of air per gallon of oil. This ratio was based on some rather elaborate tests made by an engineer about a year before, when running the furnaces with a neutral flame, a condition always aimed at to avoid both scaled and smoked stock.

Information on air and oil consumption obtained in this manner was accepted by the cost keeping department as sufficiently accurate for its needs. It was, however, a dirty messy job, took an average of an hour per furnace, including the figuring and tabulation, wasted oil and was generally hated by everyone.

To simplify all this, the problem was tackled in the following manner: First the formula for the flow of air in pipes was obtained from a text book which gave:

$$Q = C\sqrt{h}\, d^5 \div L$$

Here, Q = cubic feet of air flowing per minute; h = pressure drop in inches of water; d = inside diameter of pipe, inches, through which air is flowing; L = the length of pipe in feet over which pressure drop is measured; and C = a constant depending on the pipe diameter. This formula looked a pretty tough proposition to the man who had to get the information and he promptly said the old way of drawing a gallon of oil would be much easier and quicker for him. We talked it over, however, and began to simplify it.



AIR AND OIL CONSUMPTION CHART

We discovered that there were only four different sizes of pipes connected to the furnaces and these were No. 16 gage welded pipes of fairly accurate inside diameter. Air was carried at 1 lb. pressure in the receiver. So for a start we made a little table like this:

Pipe Diam. In.	d^5	Value of C.
3	243	41.3
4	1024	43.9
5	3125	46.1
6	7776	47.7

The next thing to decide was the length of pipe L along which the pressure drop was to be measured and we finally decided on 20 ft. because it was the longest clear straight run we could get to apply to all the furnaces, also was a convenient length. This, of course, enabled us to simplify the formula as follows:

$$Q = C \times \sqrt{1/20} \times \sqrt{d^5} \times \sqrt{h}$$

and $\sqrt{1/20} = 0.224$

With these new figures we made out a second table using a 10-in. slide rule for the calculations as follows:

Pipe Diam. In.	$C \times 0.224$	$\sqrt{d^5}$	$K = C \times 0.224 \times \sqrt{d^5}$
3	9.24	15.6	144
4	9.83	32	314
5	10.31	55.8	576
6	10.68	88.2	942

We now had a simpler formula covering the four pipe sizes used in the shop: $Q = K\sqrt{h}$

Next we took five values of h on the slide rule for each pipe size and as these could be read straight off for each setting it was a simple matter to make the next table:

h-in.	Cu. Ft. of 1-lb. air per minute, for pipes listed below: 3-in.	4-in.	5-in.	6-in.
0.1	45.5	99.3	182	298
0.2	64.4	140.3	257.5	422
0.3	78.8	172.0	315.5	515
0.4	91.0	198.5	364	595
0.5	102.0	222.0	407	666

We now had all the information needed but before making the chart we multiplied the values in the above table by 15.7/14.7 because as the air pressure in the pipe was one pound per square inch gage and we wanted the air volume at atmospheric pressure, it would expand in that ratio as soon as the pressure was relieved. By reading the increased volumes off the slide rule we charted the lines for the four different pipe diameters. Then underneath the chart we added an extra line of graduations which were simply figured by dividing the cubic feet of air per minute by 26, the figure that tests had shown was the average number of cubic feet of air per minute used for each gallon of oil burned per hour. We marked these graduations as Gallons of Oil per Hour and the completed chart was as shown in the figure.

Preparation of the various pipes was then made so that readings could be taken. On each pipe, two ⅛-in. holes were drilled exactly 20 ft. apart and ½-in. pipes were bent and welded over them. The two pipes were then brought close to each other and a pet cock attached to the end of each. This completed all the work.

Now, when the oil and air consumption of any furnace is wanted for any purpose, all that is necessary is to slip the short hose connections of a short water column U tube onto the pet cocks. Then open both of these and carefully read the pressure difference. This pressure is picked out on the left hand scale marked *h* on the chart. Then follow along a horizontal line until the line for the diameter of the pipe is reached; from this point drop vertically to the lower graduation and read directly the volume of air flowing through the pipe which is also the rate of air consumption in the furnace. Below, on the second graduated line read the rate of oil consumption of the furnace. Thus in a few minutes the air and oil rates of any furnace in the shop can be determined without interfering with production and with practically no trouble.

Note: When the small holes are drilled in the pipes, it is important to remove the fins on the inner side with a small hook scraper, otherwise these may deflect the air flow and give incorrect readings.

Steam Utilization for Economy

Saving by Utilizing Steam for Power Development. Comparison with Purchasing Current for Motors.

REQUIREMENT of steam for heating or processing brings up almost automatically the question of whether that steam may not also be profitably used for generation of current to drive motors and supply lights. Factors that enter into a decision are the degree of agreement in amounts and times of heat and power demands, investment required for power generation and cost of purchased power.

While each problem must be studied in the light of the conditions to be met, data as to results already achieved are helpful in deciding what is the wise course. For that reason, the figures which follow should be of interest. Data in each case are from Nielsen surveys but have been obtained with the collaboration and approval of some executive of the plant in each case.

Ammonia Compressor Drive

In the plant of the Brooklyn, N. Y., Home for Consumptives of which Charles L. Knudsen is engineer in charge, a 10-t. Frick compressor, 6 by 6 in., is operated with head pressure 160 lb. and suction pressure 20 lb. to hold the brine tank at 2 to 5 deg. F. Operation is 8½ hr. a day for 275 da. a yr.

Calculation showed the power needed to be 10.5 hp. for the compressor or, for the engine to drive it, 12.2 indicated horsepower.

Steam is used at 2½ lb. for house heating, hot water, sterilizing and other domestic purposes about the home. For steam supply, two 121-hp. Heine oil-fired boilers are used, delivering dry steam at 95 lb. to the throttle of an 8 by 8 in. Troy VTO engine which runs at 200 r.p.m. Two oil separators remove the oil from exhaust steam.

Under these conditions, tests showed the steam consumption of the engine to be 52.7 lb. per brake horsepower-hour, 553 lb. an hour or 4700 lb. a day. Exhaust was 95 per cent dry, hence the exhaust steam carried 92.2 per cent of the heat in the live steam. Cost of steam was determined at 80 cents per 1000 lb.

To make comparison with purchase of power, a 15-hp. motor was considered, with depreciation and interest at the same rates as for the steam engine and repairs at 1 per cent. Assuming 80 per cent motor efficiency the power purchased would be 83.22 kw-hr. a day or 22,885.5 a year. If 92.2 per cent of the steam used by the engine were required for heating, its yearly cost would be $954.25. Total cost would be $6.11 a day for motor drive and heating steam.

Compared to the $4.10 a day for engine drive, the daily saving is $2.01, that for the year is $551.80, which is 85 per cent return on the total engine investment.

Heating System Drives Its Ventilation

In the John H. Gundlach School, St. Louis, an American Blower Co. No. 11½ fan at 200 r.p.m. is used to furnish air for ventilation and heating or cooling of a 19-room building. Air is washed, cooled or heated as required, and blown to the rooms at 1½ in. pressure at the rate of 69,300 cu. ft. per min. Operation is 8 hr. a day, 20 da. a month for 10 mo. in the year.

The 36 hp. required is furnished by an 18 by 12 in. Troy engine, taking steam at 30 lb. and exhausting to the heating system at 2 lb., the exhaust steam having 90 per cent of the heat of the live steam. As heating steam would be required anyway, only 10 per cent of the cost of steam is charged against the fan drive.

Tests show a steam consumption of 34 lb. per brake horsepower-hour and cost of 49 cents per 1000 lb. of

steam, so that the yearly cost, charging 10 per cent to power, is $95.96. Oil, 80 gal. at 80 cents, is $64. Summary of costs is shown in column B.

If motor-drive were used, with depreciation and interest at the same rate as for the engine, allowance of 5 per cent a year for maintenance and $4 for oil, these would cost $131.50 a year. Motor efficiency of 80 per cent would require 53,712 kw-hr. a year and daily costs would then be as shown in Column B. The daily saving is $3.59, the yearly saving is $719.06 or 32.7 per cent of the cost of the engine.

Three like units have been installed in other St. Louis schools as a result of these savings, on the recommendation of Edward L. Stammer, superintendent of buildings, who collaborated in assembling the information given.

COMPARATIVE COSTS FOR DRIVES BY PROCESS OR HEATING STEAM USED IN ENGINE AND BY MOTOR DRIVE WITH PURCHASED CURRENT

	A	B	C	D
Plant	Brooklyn, N.Y. Consumptives Home	Gundlach School St. Louis, Mo.	Hoover Co. No. Canton, Ohio	Moulding-Brownell Corp. New Straitsville, O.
Service	Ammonia Comp'r.	Ventilation	Stoker Drive	Power & Light
Engine Plant Cost $	650.00	2200.00	510.00	2600.00
Depreo'n. 5% $	32.50	110.00	(6¼%) 34.00	130.00
Aver. Int. 6% $	20.48	69.30	16.32	81.90
Maint. & Rep. 2% $	13.00	44.00	10.20	(1%) 26.00
Fixed Chgs. $	65.98	223.30	60.52	237.90
Operation Da.pr.yr.	275.00	200.00		200.00
" Hr. " "	2337.50	1600.00	3834.00	3200.00
Brake Hp.	10.50	36.00	5.00	35.60
Steam per hp-hr.lb.	52.70	34.00	48.00	37.00
Cost stm.per 1000 lb. $	0.80	0.49	0.65	0.40
" " " yr. $	1034.00	(10%) 95.96	(8.1%) 86.35	(8.71%) 132.78
Lubrication cost yr. $	27.50	64.00	20.30	21.09
Total cost, yr. $	1127.48	383.26	167.17	391.77
" " day $	4.10	1.92		
Motor Plant Cost $	350.00	1000.00	475.00	
Depreo'n. 5% $	17.50	50.00	(6¼%) 31.67	
Aver. Int. 6% $	11.03	31.50	15.20	
Maint. & Rep. (1%) $	3.50	(5%) 50.00	(5%) 23.75	
Fixed Chgs. $	32.03	131.50	70.62	
Horsepower	10.50	36.00	5.00	
Motor Eff'y. %	80.00	80.00	70.00	
Kw-hr. per yr.	22,885.50	53,712.00	36,415.00	68,000.00
Cost per kw-hr. $	0.03	0.018	0.012	0.017
Power cost per yr. $	687.50	966.82	436.98	1156.00
Lubrication $	5.50	4.00	3.00	
Cost Stm.per yr. $ (92.2%)	954.25	-	-	1156.00
Total cost, yr. $	1679.28	1102.32	510.60	-
" " day $	6.11	5.51	-	764.23
Yearly Saving $	551.80	719.06	343.43	29.40
% On Engine Cost	85.00	32.70	67.30	

Stokers Driven by Feed-Water Heater Steam

At the plant of the Hoover Co., No. Canton, Ohio, in charge of E. W. Brong, power engineer, Green chain-grate stokers for three 342-hp. Connelly boilers have been driven by a Troy 5 by 4 in. SH engine for 3 yr. with no shut downs and no repairs to the engine. Taking steam at 160 lb. and 100 deg. superheat and exhausting at 3 lb. to the heating system or at 1½ to 2 lb. to the feed-water heater, the drive varies in speed from 100 to 300 r.p.m. delivering 2 to 6 hp. or about 5 hp. average. Steam consumption shows on test at 48 lb. per hp-hr. and operation is 134 hr. a week for 51 weeks a year.

Tests of exhaust steam showed 220 deg. at 2¼ lb. so that the heat content of exhaust steam would be 91.9 per cent of that for live steam or 8.1 per cent of steam cost is chargeable to the engine at 65 cents per 1000 lb. Investments, fixed charges, operation costs and totals for the engine drive and for equivalent motor drive are given in column C. Oil used per year is 15 gal. machine oil at 50 cents and 32 gal. cylinder oil at 40 cents. Motor efficiency is taken as 70 per cent. Depreciation period of 15 yr. or 6¾ per cent yearly allowance is made for both drives on account of severe conditions. The yearly saving, $343.43, returns 67.3 per cent on the cost of the engine installation, which should be a satisfactory rate.

Dry Kiln Steam Furnishes Power and Light

Data from the generating plant of Moulding-Brownell Corp. were furnished by collaboration of J. W. Blum, ceramic engineer. Steam is required for a 16-hr. night shift to dry moulded ceramic blocks preparatory to firing and power is needed to operate motors for the kiln oil burners, to drive a compressor and a hoist, also some current for lighting. The plant is operating 200 da. a year.

Dry steam is supplied by three 150-hp. h.r.t. boilers at 115 lb. and exhaust is at atmospheric pressure, the engine using 8.71 per cent of the heat in the live steam.

To supply current, an Engberg engine-generator set is used, load averaging 21¼ kw. at 250 v. The engine is 10 by 9 in.; generator rating 30 kw., speed 300 r.p.m. Brake horsepower averages 32.2 hp. at which steam consumption is 37 lb per hp-hr.

During the day, the load is carried by a 200-hp. steam engine.

As the only maintenance on the Engberg set during 5½ yr. service has been replacement of packings and minor adjustments, a nominal 1 per cent is allowed for that expense. Steam cost is 40 cents per 1000 lb. and 8.71 per cent of steam cost is charged to the engine. Annual output is 68,000 kw-hr. and cost of purchased current is 1.7 cents per kw-hr.

Summary of cost for generating and for purchasing power is shown in column D, the difference in favor of generating being $764.23 a year, or 29.4 per cent on the cost of the generating set.

POWER PLANT ENGINEERING August 15 1932

Friction of Air in Elbows

TESTS AT THE ENGINEERING EXPERIMENT STATION OF OHIO STATE UNIVERSITY SHOW THAT WELL ROUNDED ELBOWS HAVE LOWER FRICTION LOSSES THAN SQUARE ELBOWS WITH GUIDE VANES. BY A. I. BROWN*

ABOUT FIVE YEARS AGO, the General Electric Co. reported the results of tests made primarily for establishing the best design of cast iron connections between the turbine and condenser. Results of these tests have created a great deal of interest and have been used in the design of sheet metal elbows used in ventilating systems, smoke breechings and forced draft ducts.

One of the results of the tests which has created the most interest is the conclusion that in a duct of square or rectangular section an elbow having a square outer corner offers 10 per cent less frictional resistance to flow than one having a rounded outer corner. This result appears to have been entirely misinterpreted by some people and a popular notion is occasionally found among sheet metal workers that an elbow with a square inner corner as well as a square outer corner is better than the conventional form of elbow which has both inner and outer corners curved with a liberal radius such as a

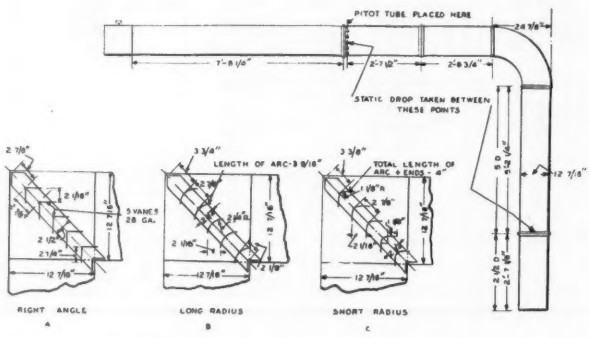


FIG. 1. ARRANGEMENT OF APPARATUS AND SKETCH OF VANE DESIGN

center line radius of 1½ times the width of the duct.

A second result of the General Electric Co. tests is that the introduction of suitable guide vanes in a square-corner elbow reduces the resistance to such an extent as to show even better results than are found in tests of the conventional rounded-corner elbow having a center line radius of 1½ times the width of the duct.

Observations that, in the report of the General Electric tests the so-called square-corner elbow of cast iron was illustrated as having corners which were slightly rounded and that guide vanes of varying thickness such as were used are not of convenient form to be made in a sheet metal shop have suggested the question of the effect of guide vanes of uniform thickness inserted in a sheet metal elbow having sharp right-angle corners. In view of the results produced by a square outer corner the question also has arisen as to the effect of right-angle guide vanes in a square elbow. Although the General Electric Co. publication did not state the lower limit of the air velocities employed in the tests, it implied the use of much higher velocities than are common in the field of ventilation. This leads one to wonder whether similar results would be found at velocities usually prevailing in sheet metal ducts.

With the hope of answering the foregoing questions, tests, under the supervision of the writer, were conducted by W. S. Payn and J. M. Stelzer, students in mechanical engineering, as the basis of a joint thesis presented for their bachelor degrees.

APPARATUS AND METHOD OF PROCEDURE

In the set-up of apparatus for testing, Fig. 1, air was discharged by a centrifugal blower through a 12½ ft. length of 12-in. square sheet metal duct, then through the elbow to be tested and finally discharged to the atmosphere through a 7½ ft. length of duct of the same size. Air velocities were varied through a range of about 1500 to 3000 ft. per min. by variation in fan speed.

Tests at four different velocities were conducted on each of the following elbows: a square-corner elbow; a square-corner elbow with five vanes in the shape of 90 deg. angle irons, each side of the angle being 2¼ in. wide; a square-corner elbow with five vanes in the shape of circular arcs 3.9 in. long and with a radius of 2¼ in., termed long-radius vanes; a square-corner elbow with five vanes in the shape of a compromise between angle irons and circular arcs; a curved elbow of the conventional form with a center line radius of 18 in. or 1½ times the width of the duct. All vanes of the various forms were made of No. 26 ga. galvanized steel

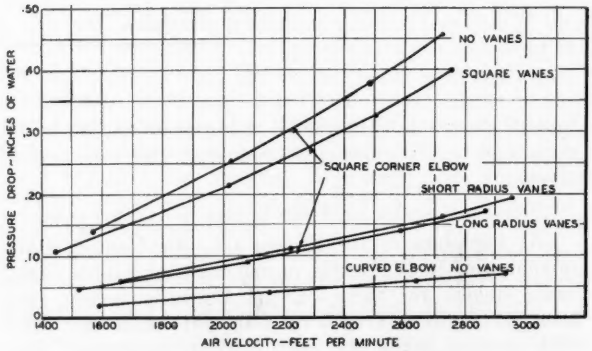


FIG. 2. PRESSURE DROP FOR DIFFERENT VELOCITIES

of a length equal to the entire width of the duct minus the thickness of two side strips of similar metal to which the vanes were attached so as to hold them equally spaced.

RESULTS OF TESTS

Frictional resistance of the conventional form of curved elbow and of the square elbow with the various shapes of blades varied, as would be expected, in direct proportion to the square of the air velocity, Fig. 2. Since this was found to be true, it is most convenient to express the various resistances in terms of the velocity pressures corresponding to the various velocities, inas-

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much as the velocity pressure is likewise proportional to the square of the velocity.

In only one of the twenty tests did the variation in frictional resistance amount to more than one per cent of the corresponding velocity pressure. In that test the variation was 3 per cent. Therefore, in view of the consistency of the results at the various velocities, the average frictional resistance in per cent of velocity pressure, Fig. 3, will suffice to show the comparison for the different elbows and vanes.

Resistance of the square-corner elbow without vanes averages 103 per cent of the velocity pressure and was higher than for any of the other designs tested. Introduction of guide vanes of the shape of angle irons into the square-corner elbow reduced the frictional resistance from 103 to 88 per cent of the velocity pressure. Vanes of short radius did not show quite as good results as those of longer radius, offering a resistance equal to 38 per cent of the velocity pressure.

Least resistance was found in the tests of the conventional elbow of square cross-section but having both the inner and outer corners well rounded, the center line radius being equal to 1½ times the dimension of the side of the square section. This resistance was only 14 per cent of the velocity pressure.

Discussion of Results

A comparison of the results of tests of the square-corner elbow and the curved elbow of conventional form, both without vanes, shows that the square-corner elbow offers nearly 7½ times the resistance of the well-rounded elbow. These results show the folly of using a square-corner elbow without guide vanes where space would permit the use of a well-rounded elbow.

Introduction of guide vanes into the square-corner elbow effects a reduction in frictional resistance, the greatest reduction being effected by vanes which produce a gradual rather than an abrupt change in the direction of air currents. Where space limitations prevent the installation of a well-rounded elbow and a sharp elbow must be used, its resistance may be greatly reduced by the use of well-rounded sheet metal vanes, but this combination of sharp elbow and vanes such as were used in these tests will offer more resistance than a well-designed curved elbow.

Results of these tests are in agreement with the well-known principles of aerodynamics that turbulence and friction are lessened by gradual rather than by abrupt changes in direction of flow and that the friction of air against a smooth surface, is less than that which is produced by air currents of different velocities or of different direction rubbing against one another. Where no vanes are provided in an elbow the tendency is for the air to crowd into the outer corner with the result that different velocities are produced across the section of the duct and friction is increased. Vanes act to divide the elbow into a number of channels through which the air is guided at more uniform velocities.

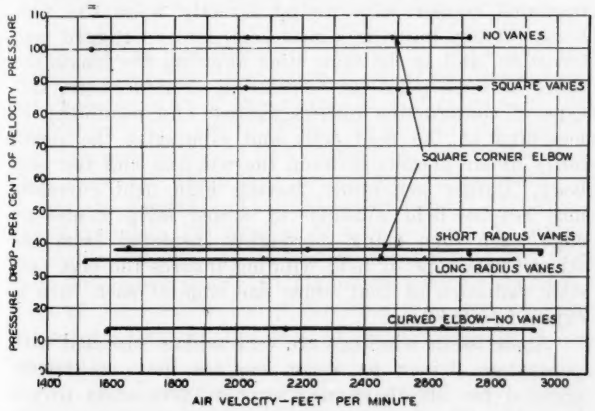


FIG. 3. PRESSURE DROP AS A PERCENTAGE OF THE VELOCITY PRESSURE REMAINS PRACTICALLY CONSTANT FOR ALL FLOWS

Results which show the effect of the guide vanes in reducing friction suggest the likelihood of improvements in the curved elbow by the application of guide vanes. Such vanes or splitters in well-rounded elbows are coming to be used quite generally where such an elbow is located close to an outlet in the duct system. In this location the vanes serve to produce more nearly equal velocities at all positions over the face of the outlet grille and thereby improve diffusion and prevent drafts; but in providing more uniform velocities reduced friction, no doubt, results. In view of the excellent performance of a well-rounded elbow in square ducts, the reduction in frictional resistance which might be effected by the use of guide vanes would necessarily be slight in comparison with the improvement produced by the use of similar vanes in a sharp elbow.

Novel Lubricant Regulation

In discussing lubrication problems with a real lubrication expert not long ago, he informed me of an interesting method where he does the diametrical opposite of what is commonly done in lubrication, namely, he adds lubricant on *stopping* the motor instead of when *starting* it. He doesn't merely add a few drops with an oil can; he turns on a sight-feed oiler, a method that was new to me.

He explained that he uses this method only in connection with the lubrication of ball and roller bearings which are adjacent to a source of high temperature. In other words, it is his pet scheme for successfully lubricating bearings which ordinarily give trouble due to excessive heat.

I asked, "Why do you do it in that way? Is it for the purpose of adding a new supply of oil, or, does the oil serve as a coolant?"

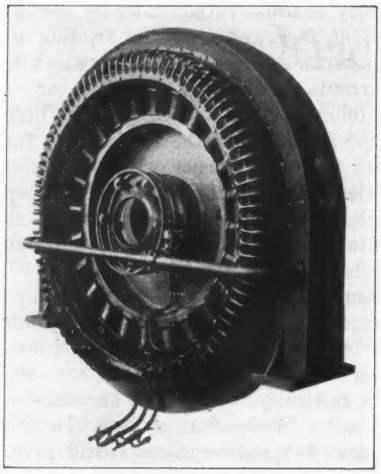
"No," he informed me, "I do it in order to keep the grease from hardening. On giving the matter thought you can readily see that, if the oil were applied directly to the grease while the motor is in motion, it would have no chance to be absorbed by the grease because centrifugal force would cause the oil to throw. In this manner I have been successful in taking care of surprisingly high temperatures."

It sounds like good logic, doesn't it? The fact that it does the trick proves that it *is* good logic and good logic is always bound to result in sound engineering practice.

W. F. Schaphorst.

At a cost of $7000 a St. Louis plant stopped air leakage through sides and back end of a chain grate stoker, replaced sprung arches by a flat suspended arch and installed steam flow meters. Result,—better efficiency and use of a lower grade fuel saved $15,000 the first year.

POWER PLANT ENGINEERING August 15 1932



ENGINE TYPE GENERATORS

Improvements in the design of reciprocating steam engines and Diesel engines have materially increased the use of engine type generators. In order to guide those purchasing or using such generators the characteristics of engine type generators are described in this article.

By FRED J. SCHWARZ
General Electric Co., Schenectady, N. Y.

IMPROVEMENTS IN THE design of the reciprocating steam engine, the application of the unaflow principle and consequent higher speeds for steam engines, and the advent of the Diesel engine in the power field have materially increased the use of engines as prime movers for electric generators. These developments in engine practice have brought new problems in generator design, and the improvement in insulation materials and the advance in the art of welding have wrought many changes in generator construction.

Engine Type Alternating Current Generators

The stationary element or stator of an engine type alternating current generator consists of a frame supporting the laminations having, in their inner circumference, slots in which the armature windings are imbedded. The rapid advances made in the welding art have made a radical change in the construction of stator frames. Previous to about 1925 cast iron was used almost exclusively in the construction of stator frames. Cast iron is, of course, brittle and is liable to crack under sudden shocks. It is also subject to casting strains, sand holes, etc., all of which decrease its mechanical strength. Fabricated steel, on the other hand, eliminates all of these objectionable features. The modern generator has a completely fabricated frame consisting of end plates or sides cut from heavy steel plate. The stator punchings are held between these plates by through bolts and a "wrapper" plate is formed around the outside periphery of the end plates and welded to them. This wrapper plate gives the frame increased strength and rigidity and also a more pleasing appearance (Fig. 2).

The stator, or armature, core is built up of accurately punched laminations, carefully annealed, insulated and assembled in such a manner as to minimize both hysteresis and eddy current losses. Ventilating ducts are provided, where necessary, in the punching stacks to allow free circulation of the air. The core is provided with open type slots in which the armature coils are placed and held by suitable wedges.

Stator coils are form wound, uniform in shape and interchangeable so that they may be readily replaced if damaged. It is essential that the insulation of the stator coils should have ample dielectric and mechanical strength and endurance under service conditions such as resistance to heat, dirt and moisture, freedom from air pockets and flexibility to withstand distortions. This is effectively obtained, for voltages below 6600 v., by insulating the coils with tapings of fabric treated with special insulating varnish and filling with moisture resisting compound.

While rotor spiders of cast iron are still frequently used, a more rigid construction can be obtained by fabricating the spider from rolled steel. This type of rotor spider may take the form of a rolled steel rim welded to a solid steel plate center to which a rolled steel hub is welded.

Rotor spiders are supplied either solid or split depending on conditions existing for assembly on the engine shaft or upon shipping dimension limitations. Cast spiders can be supplied solid, (Fig. 1), split (Fig. 3). Fabricated spiders can be supplied either solid (as shown in the photograph at the head of this article), or split as in Fig. 4.

Pole pieces are built up from high quality steel laminations securely riveted together and reinforced by stiff end plates. They are secured to the rotor spider by means of heavy bolts or other approved means in such a manner as to insure the best magnetic circuit and minimize the magnetic leakage between poles. The field winding may consist of copper wire or of copper strip wound on edge. Generators of small size may have insulated copper wire wound directly upon the pole body, thereby insuring a most compact and rugged construction, and at the same time allowing the maximum space between poles for ventilation. Furthermore, this type of construction insures against any possibility of loosening of the field coils and eliminates the possibility of air pockets between the winding and the pole body. Larger generators, having high field currents, may require field windings of copper strip wound on edge, each turn being thoroughly insulated from the other. This type of field winding insures the best possible radiation of heat, since one edge of each turn is exposed to the air.

Amortisseur windings are very seldom supplied with generators driven by steam engines, but are recommended for all alternating current generators driven by internal combustion engines, in order to dampen out any oscillations which may be occasioned by the pulsating torque of the engine. The amortisseur winding con-

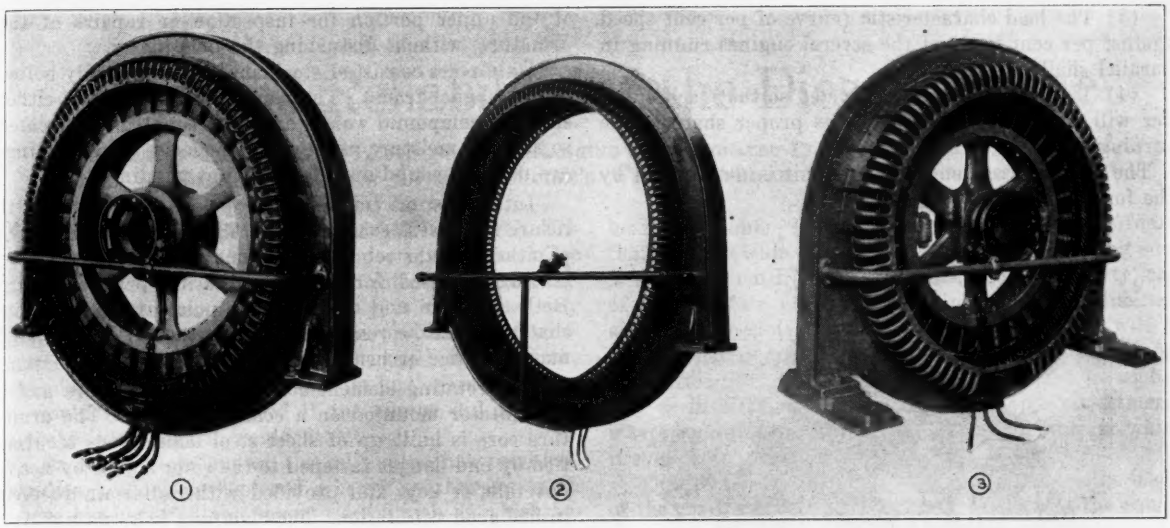


FIG. 1. A. C. GENERATOR WITH SOLID CAST ROTOR. FIG. 2. WELDED PLATE STATOR FOR A. C. GENERATOR. FIG. 3. A. C. GENERATOR WITH SPLIT CAST ROTOR.

sists of copper bars inserted in holes in the pole tips and connected at both ends by heavy copper end segments designed to permit easy removal of any complete pole.

It is common practice to use best quality cast iron for the collector rings and insulate them with bushings of high dielectric strength. In those locations where the atmosphere contains such chemicals as would cause the cast-iron rings to corrode or rust, bronze collector rings are sometimes used.

When two generators driven by reciprocating engines are connected in parallel and supply power to a steady load, pulsations in the engine torque may cause a transfer of power of greater or less magnitude back and forth between the machines depending on the characteristics of the engines, the total WR^2 or flywheel effect of the engine flywheels and generator rotors, and the characteristics of the generators. These pulsations may be of small magnitude and, therefore, harmless, or of a magnitude sufficient to increase the mechanical stresses and heating of the machine, and if sufficiently great may cause the generators to fall out of step. Experience has shown that a power pulsation of approximately 66 per cent is the maximum that may be safely allowed to avoid injurious heating or other undesirable conditions.

It is usually desirable to determine paralleling conditions before the units are completely built and installed. Inasmuch as the power pulsations depend on the characteristics of the engines as well as those of the generators which are to operate in parallel, the following information should be available on each engine and each generator which is to be operated in parallel.

On the Engine: (1) Horsepower rating, (2) Number of cylinders, (3) Number of stroke cycles, (4) Single or double acting, (5) Amount of unbalance of any one cylinder continuously, (6) Maximum periodic displacement of the rotor in either direction from the position of uniform rotation, (7) WR^2 of the flywheel (in ft. lb. squared).

On the Generator: (1) Kv-a. rating, (2) Power factor, (3) Frequency, (4) Speed in r.p.m., (5) WR^2 of rotor (in ft. lb. squared), (6) P_s—Synchronizing power or rate of change of power with respect to the displacement angle expressed in kw. per electrical degree.

With the above data at hand an approximate check as to successful parallel operation can be made by the "Natural Frequency and Angular Deviation Rule," which may be stated as follows: To insure successful parallel operation of alternators driven by reciprocating engines, the following conditions must be fulfilled:

(1) The total flywheel effect of each of a number of generating units operating in parallel shall be such that (a) During parallel operation the maximum periodic displacement of the rotor in either direction from the position of uniform rotation does not exceed $3\frac{1}{2}$ electrical degrees. (b) The natural frequency of operation of each unit or the combined natural frequency of any two units will differ at least 20 per cent from the frequency of any forced impulse.

(2) The engine governors shall not create or sustain an oscillation.

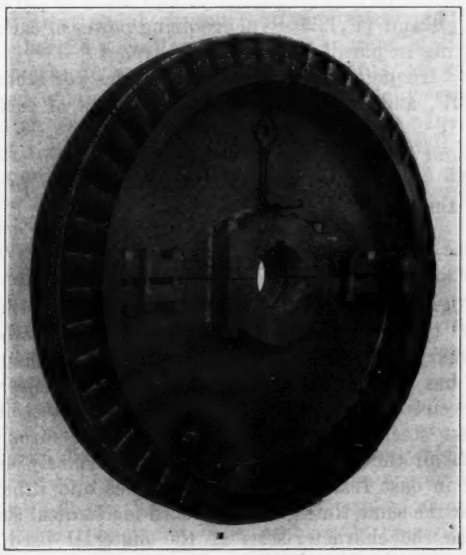


FIG. 4. SPLIT ROTOR WITH FABRICATED SPIDER

(3) The load characteristic (curve of per cent speed against per cent load) of the several engines running in parallel shall be alike.

(4) The engine shall be adjusted so that each cylinder will contribute successively its proper share to the turning effort.

The natural frequency of any unit is determined by the formula:

$$F = \frac{266{,}500}{\text{r.p.m.}} \sqrt{\frac{P_s \times f}{WR^2}}$$

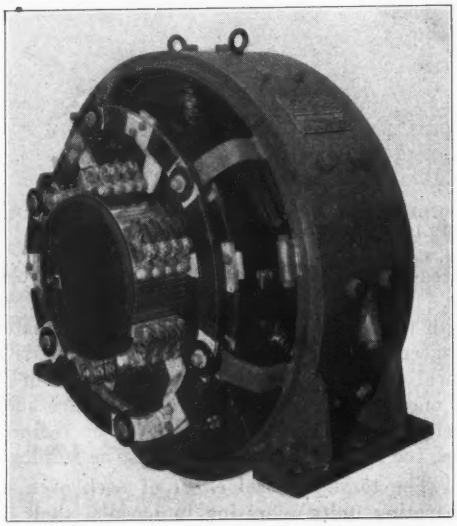


FIG. 5. ENGINE TYPE DIRECT CURRENT GENERATOR

and the combined natural frequency of two units operating in parallel by the formula:

$$F_{1+2} = \frac{266{,}500}{\text{r.p.m.}} \sqrt{\left(\frac{(P_s)_1 \times f}{WR^2_1}\right)} \times \sqrt{\left(\frac{1+\frac{WR^2_1}{WR^2_2}\left(\frac{P_2}{P_1}\right)^2}{1+\frac{(P_s)_1}{(P_s)_2}}\right)}$$

Where F = Natural frequency of one unit.

F_{1+2} = Natural frequency of two units in parallel.

$(P_s)_1$ and $(P_s)_2$ = Synchronizing power of each unit, operating in parallel as defined above.

f = frequency of generators in cycles per second.

WR^2_1 and WR^2_2 = total flywheel effect of each unit in lb. ft.^{2}

P_1 and P_2 = Number of poles of each unit.

The above rule is approximate but will probably cover the majority of applications.

Direct Current Generators

Engine type direct current generators, like the engine type alternating current generators, consist of a stationary and a rotating element. The stationary element has a steel frame supporting the field poles on its inner circumference. A frame of rolled steel instead of cast steel insures a uniform magnetic circuit and avoids all the difficulties which were formerly encountered in cast frames due to blow holes and sand holes and at the same time gives increased mechanical strength due to the characteristics of the material used. The frame is split horizontally, permitting the easy removal of the upper portion for inspection or repairs of the armature, without disturbing the pole pieces.

Main poles consist of steel laminations securely bolted to the magnet frame. The main field coils may be either shunt or compound wound and are insulated and treated so as to be moisture resisting. The series field windings are usually wound outside the shunt windings.

Interpoles or commutating poles are provided to insure successful commutation. These poles may consist of either rolled steel or laminations. Copper strip wound on edge is used for the commutating field windings. Both the main and commutating poles are so arranged that they can be removed without interfering with the magnet frame or brush rigging.

The rotating element consists of an armature and a commutator mounted on a common spider. The armature core is built up of sheet steel laminations securely tied by end flanges fastened to the rotor spider by heavy dovetails or keys and provided with radial air ducts to insure good ventilation. The clamping bolts do not pass through the laminations.

The armature spider on which the core is supported may be of cast steel or reinforced cast iron having sufficient strength to resist the stresses of an irregular turning movement which is present in all reciprocating engines. The armature conductors are form wound, uniform in shape and interchangeable to permit easy removal and replacement when damaged.

The commutator should be of hard drawn copper segments having ample wearing and radiating surface. These segments should be insulated from each other with best quality mica, undercut between segments, thereby permitting the use of graphite or self-lubricating brushes. The segments should be of sufficient length to permit staggering of the brushes. In order to facilitate assembly and disassembly of the armature on the engine shaft, the commutator should be mounted on an extension of the armature spider and not directly on the shaft. Brushes should be supported from the magnet frame by a substantial brush holder yoke and adjustable brackets. The brush holder should be of the coil spring or other approved type for obtaining any desired pressure and capable of adjustment while the generator is running.

Engine type direct current generators are usually compound wound and will operate successfully in parallel if the series fields are properly equalized.

Contrast of the results from private and governmental management of power systems is shown in the development of the Susquehanna River as compared to Muscle Shoals and the Tennessee River. Over a 5-yr. period, on the Susquehanna have been developed Safe Harbor, Conowingo and Holtwood, in service and the power sold. Muscle Shoals has been a political football with no scoring. The latest aberration of Congress is a bill allowing 18 mo. to lease the nitrate plants, under conditions that make such a lease practically impossible, and, if not leased, operation chiefly for fertilizer production by a board, which the bill would create; just another government rat hole to swallow money for the Muscle Shoals nitrate plant is hopelessly out of date as a method for nitrate production. Taxpayers would foot the bill for improvements and deficits in cost of operation, as is usually the case in government activities.

Cost and Reliability of the Diesel Engine

RECORDS OF TEN REPRESENTATIVE STATIONS RANGING FROM ISOLATED PLANTS TO PEAK LOAD SERVICE. LACK OF SKILLED OPERATORS GIVEN AS ENGINE'S WORST HANDICAP. BY GEORGE CHARLESWORTH*

WHILE THE INTERNAL COMBUSTION ENGINE has been a practical power unit for more than half a century and the laws which govern its efficiency were worked out rather early, it is only recently that it has become a factor in the production of commercial power. With its high thermal efficiency, the abundance of cheap fuel oil and its low operating costs, it would be strange indeed if the engine did not find a niche into which it would fit.

Rapid development of the oil engine has produced handicaps which have placed a heavy overburden on it. Large amount of development work, much of which became obsolete almost before completion, has made the manufacturing of oil engines expensive and not too profitable to the manufacturer. The high initial costs and the uncertainty as to its life have made it expensive to sell. The heavy investment costs have given it expensive overall operating cost. It is not uncommon, for capital costs to be twice or three times as much as the total cost of operation even when the load factor is relatively high.

On the other hand there are special operating advantages which make the engine attractive to producers of power. Its operating costs are low, especially in the smaller sized units. The space occupied is small as compared with steam engine and boiler plant. The speed with which it can be put into operation makes it valuable as reserve units. It is also suited to automatic control which gives it great value as a reserve unit. Progress is being made in this field and it would seem that this phase of the oil engine development has already started.

CONTROVERSIAL COSTS

Perhaps the most unfortunate factor connected with the oil engine is that its very nature makes it the agent of much political and power company propaganda. In gathering material for this paper I could not help but notice the tendency of the proponents of internal combustion engines to use only a portion of the facts and the tendency to exaggerate the importance of those facts which tended to prove too often the prejudice of the party using them. It must be explained, however, that almost without exception the data given out was found to be correct even when some very important cost factors are often entirely omitted. On the other hand power engineers are prone to exaggerate grossly maintenance costs. The writer was, however, fortunate in being able to analyze the capital expenses and operating costs of several publicly and privately owned plants where enough data were available to make a complete study of both capital and fixed costs as well as operating expenses.

There were chosen from the mass of data collected a number of plants which seem fairly typical. These range all the way from a small isolated plant to peak load only plants. In studying these records it was found that there is wide divergency of opinion regarding such items as the nature of investments, life of property, cost of money, fair charge for engineering. To eliminate as far as possible the controversial matters, it will be stated clearly just what enters into each item. It has been attempted to set out each item of cost in such a way as to make it possible to make proper adjustments where conditions are different from the conditions which prevailed in the plants studied.

Cost of the plant in each case is taken from the books of the company and is made up of the cost of the equipment; the value of the real estate; the cost of the building; the cost of erecting equipment and the carrying of all power connections to the building wall ready to be connected to the lines; engineering, legal expenses and superintendence are added as general expense items at cost.

TABLE I. BRIEF DESCRIPTION OF STATIONS COVERED BY DATA IN TABLE II.

No. 1.	1—237 kv.a; 1—75 kv.a. 2 cycle solid injection, small town local—near coal field.
No. 2.	1—300 kv.a. 4 cycle air injection; 1—200 kv.a. 2 cycle solid injection; 1—75 kv.a. 2 cycle solid injection isolated district, bad water.
No. 3.	2—513 kv.a. 4 cycle air injection. On opposite end of distributory system with No. 4 has reserve capacity for both.
No. 4.	1—585 kv.a. 4 cycle air injection.
No. 5.	3—513 kv.a. 4 cycle air injection; 1—250 kv.a. 2 cycle solid injection. Tied in with hydro and steam stations. Operates near full load or shuts down.
No. 6.	3—600 kv.a. 2 cycle solid injection. Located at junction of 3 transmission systems, reserve for all.
No. 7.	2—512 kv.a.; 1—375 kv.a. 4 cycle air injection. Tied in with hydro-station but is major source of power. Major overhaul in 1930 increased maintenance expense to $0.0046 per kw. hr. No city tax.
No. 8.	1—690 kv.a. 2 cycle solid injection. Peak load.
No. 9.	1—690 kv.a. 2 cycle solid injection. Peak load.
No. 10.	1—525 kv.a.; 1—300 kv.a.; 1—200 kv.a.; all 2 cycle solid injection. Peak load.

NET AND GROSS GENERATION

In arriving at the current manufacturing costs, I have charged such items as exciter current, station light and power to operation; in other words, all costs are figured on the net amount of current delivered to the building wall for sale or other uses. In this paper where all of the current generated is used, it is followed by the word "gross." Where current which is delivered to the lines for sale is referred to, the word "net" is added.

When the cost of selling securities, floating bonds and other costs of financing are properly allocated, the real cost of money is far in excess of the nominal rate. In studying this phase of the problem, the writer finds that 6 per cent base rate money usually costs somewhere between 7 and 7¼ per cent.

There is a wide range of opinion as to the life of oil engines and to their maintenance costs. There is much academic discussion regarding the relation which should exist between these two items which the writer does not desire to dodge. He recognizes the problem as one separate from this paper. The problem is receiving much study by commissions, accountants, engineers and

*Iowa Railroad Commission, Des Moines, Iowa. From a paper presented at the Tenth Annual Conference of the State Utility Commission Engineers at the Bureau of Standards June 1932.

others with the result that it is coming to be accepted that the total value of these two items will fall somewhere between 4 and 5 per cent.

Recognizing these factors and others, the writer has used an arbitrary figure based on 20 yr. life for the plant as a whole. He knows full well that properties which are well maintained will have a smaller depreciation factor and that those which have lower maintenance standards will have higher depreciation.

The point is clearly brought out when a study of maintenance costs is made; no matter how carefully a plant is maintained, there always comes a time when the plant must have a major overhauling. These major overhauls are expensive and usually lay the unit up for a much work remains to be done in the field of proper application. While the engine has great merit, it has very definite limitations.

Virtues of the Diesel engine are: Great economy of operation especially in the small sized units; reliability as shown by a study of power house reports; efficient operation far from the coal field and in localities of bad water; ease and quickness with which it can be put into service makes it an acceptable reserve source of power; applicable to automatic control; relatively large sized units can be made portable (300 kv.a. of capacity can be handled in 3 railroad cars); in municipal operation where interest and taxes are charged to the taxpayers the oil engine is particularly attractive.

TABLE II. TOTAL AND UNIT COSTS OF 10 PLANTS FOR THE YEAR 1931.

Plant	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Total kw.hr. generated	229080	747510	2258800	1549330	1651300	1919770	2502301	842266	930665	1006875
Kw.hr. light and power	11571	40990	50979	27260	18536	80285	75558	13386	14800	11635
Kw.hr. station losses	8619	12460	512	17211	19757	21572	20053			
Net kw.hr. for use	208890	694060	2207300	1504859	1612957	1789653	2406690	828880	915865	995240
Station capacity kv.a.	309	575	1026	585	1786	1800	1399	706	706	761
Maximum demand kw.	85	245	950	630	1700		1100	610	560	550
Fuel oil used gallons	39944	97972	212601	140875	138444	207547	239705	61571	75685	94171
Cost of oil, fuel	$1622.84	$3654.82	$8449.16	$5588.34	$5701.78	$6918.12	$9451.04	$2562.57	$2826.26	$3445.91
Cost of oil f.o.b. plant	$ .041	$ .037	$ .04	$ .04	$ .041	$ .033	$ .039	$.0416	$.0373	$.0367
Net kw.hr. per gal.fuel	5.22	7.08	10.38	10.68	11.65	8.62	10.04	13.4	12.1	10.5
Gallons lubricating oil	633	1863	1745	685	1987	2861	2780	1117	760	932
Cost of lubricating oil	$ .50	$ .55	$ .51	$ .52	$ .50	$ .50	$ .50	$ .488	$ .488	$ .557
Net kw.hr. per gal.lub.oil	330	373	1265	2197	812	626	866	740	1205	1067
Detail Cost Statement in Dollars per Kilowatt Hour										
Int. @ cost of money	$.0255	$.0142	$.0065	$.0055	$.0144	$.0129	$.0077	$.0087	$.0075	$.0106
Wear out 20 yr. life	.0120	.0070	.0038	.0027	.0071	.0064	.0038	.0042	.0036	.0051
Taxes	.0086	.0026	.0014	.0013	.0003	.0022	.0002	.0021	.0024	.0025
Fuel cost	.0078	.0053	.0038	.0038	.0035	.0039	.0039	.0031	.0031	.0035
Lubricating costs	.0015	.0015	.0004	.0002	.0006	.0008	.0006	.0006	.0003	.0005
Operating labor	.0106	.0052	.0018	.0030	.0020	.0021	.0020	.0036	.0030	.0035
Water	.0002	.0004	.0002	.0002	.0002	.0001	.0002			
Maintenance	.0063	.0047	.0015	.0011	.0008	.0014	.0017	.0018	.0009	.0016
Miscellaneous	.0008	.0004	.0002	.0004	.0001	.0007	.0003	.0009	.0007	.0008
Insurance								.0001	.0001	.0002
Total power cost	$.0733	$.0413	$.0190	$.0182	$.0290	$.0305	$.0201	$.0251	$.0216	$.0283

week to several weeks. Plant No. 7 was selected because in 1930 it had one of these general overhauls. Maintenance figures used in these reports are the actual money spent.

Mean Cost $225 per kv.a. of Capacity

After visiting many power houses and studying many cost of construction reports and operating statements, plants were chosen each of which illustrates a typical application of the Diesel engine. These plants are all well planned and economically built; in each case the original plans, specification and construction cost data were available. The highest cost, $259.65 per kv.a. of capacity was for one of the small plants. The cheapest was $182.72 per kv.a. for a plant which was installed in a building which had formerly been used as a steam plant. The mean cost was close to $225.00 per kv.a. of capacity.

Each of these plants is in charge of a man well skilled in the operation of such units and the plants chosen render service in four states.

There are other plants which could have been used to illustrate the various types and classes of service but these are sufficient and represent good engineering practices and good examples of careful and efficient operation for the conditions under which they operate.

Visiting of plants for the purpose of observing engineering practices and study of operating statements has led me to believe that the Diesel engine unit has a rather definite place in the power industry, but that

Limitations of the Diesel engine are: High initial cost, making excessive overhead costs; (in all cases studied the interest on the investment, depreciation and taxes were more than twice the power production costs); the plant to be economical must have a higher load factor than can be secured in the average small system; the life of the unit is as yet a question; the rapid development of the art will make obsolescence a greater factor than wear out; the public has not yet learned that Diesel engines require high type care; the wide variation of efficiencies and costs under different operating conditions has made average results very misleading; on account of the sluggish governing systems units of different makes do not run well together; the relatively low operating costs as compared to the overhead, non-cash accounts, lead many people to misjudge the total cost of power.

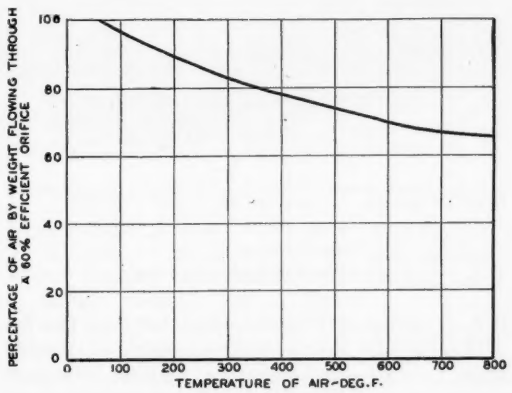
For rubber belting protection during a protracted shut-down the following suggestions are given by B. F. Goodrich Co. Store in a dark place at not over 70 deg. F. and not too dry, away from direct sunlight and warm air. For rolls, treat the edges and exposed faces with the following solution, applied with a whitewash brush: One qt. shellac; 1 pt. alcohol; 1½ qt. household ammonia; 3 qt. water; all mixed thoroughly. One gallon should cover about 300 sq. ft. For short shut-downs where belts are not to be taken off, be sure that all tension is removed.

Readers' Conference

Combustion Balance with Preheated Air

IN OPERATION of oil furnaces that are supplied with air fed through a preheater, it is important to watch out for air shortage as the furnace heats up. In most of these furnaces the air is heated by the waste gases, so gets to proper temperature only after the furnace has been running some time. In large furnaces it may be one or several hours before the air supply temperature becomes constant.

At first thought, it might seem that increase in the air temperature would result in increase, if anything, in the amount of air delivered. True, increase in temperature at constant pressure does result in slight increase in velocity of the air through the inlet orifice, which means an increase in the number of *cubic feet* of air delivered per minute. The fallacy is in thinking that it takes a certain number of cubic feet of air to burn a



RELATIVE AIR DISCHARGE AT CONSTANT PRESSURE FOR VARYING TEMPERATURE

gallon of oil, which is true only if temperature of the air is specified; for a certain weight of air at say 70 deg. F. will be 100 cu. ft., while this same weight of air at 600 deg. F. will occupy a volume of 200 cu. ft. In this case it would take exactly twice as many cubic feet to burn a gallon of oil as it did when the air was at 70 deg. The best way to talk about the air required for combustion is in pounds; then the temperature can cause no error.

Volume of air per pound increases at much faster rate with rise in temperature than does velocity and so the final result is that the weight of air entering the furnace is decreased. If the oil supply has been set constant, all this means that with combustion balanced correctly when the furnace is started, it soon gets considerably out of balance. It is a mighty good idea to put a thermometer in the air supply and, as long as the temperature is rising, to keep making the necessary adjustment in order to keep the combustion in proper balance. The thermometer should be one of the high-temperature, gas-pressure type, for preheated air of 600 to 800 deg. F. is not uncommon.

Preheated air has one advantage that tends to correct somewhat for the decreasing weight, that is, as the temperature increases, the combustion tends to become easier and more perfect, so that you will get good combustion with less excess air. If you test with a CO_2 indicator, however, you will get the right balance under all conditions.

In order to give some idea of what happens to the air delivery, the chart shows how the weight of air flowing through an opening 60 per cent efficient varies as the temperature increases when starting with 70 deg. air.

Moline, Ill. GEORGE P. PEARCE.

Babbit Melting Rig

ONE OF OUR millwrights who is also a good blacksmith always kicks up a row in the shop whenever anybody melts a ladleful of babbit metal in the forge fire—says he can't weld anything after babbiting has been done! Is this man correct and, if so, how can a babbiting apparatus be used without causing a row?

This question recently put to me drew the following reply:

Your blacksmith-millwright is right. After a little lead has gotten in the forge fire, welding simply can't be done until after the fire has been thoroughly cleaned and every particle of lead and other soft metals is removed from the fire, tuyere, air-pipe and coal in and around the fire. The oxides which are driven from lead and tin by heat, coat iron and steel and prevent welding while such oxides are present.

Sometimes, when only a small quantity of the soft metal has been spilled in a forge fire, it may be removed by building a heavy fire and keeping on a good blast for 10 or 15 min., meanwhile, scattering several handfuls of salt into the fire. But, if it is suspected that the melted soft metal has been spilled in quantity, then remove all the coal from in and around the forge fire, clean out the forge thoroughly, and even open the tuyere and the blast pipe and remove any metal which may have found its way there.

If there is compressed air in your mill a babbit melting ring is easy to make. Procure a large cast-iron pot, at least a foot in diameter and with thick, heavy walls. The pot which is suitable for babbit melting, has a smooth, round bottom, with no square corners or projecting section.

Suspend the pot by means of a stout chain, or a rod, from a safe fastening somewhere overhead. Hang the melting pot to the rod or chain by means of a stout high bail, which will keep the chain or rod hook far enough above the pot to permit of dipping babbit from the pot with a ladle, or putting into the pot journal bearings from which the lining is to be melted out. The bail should be high enough that such work can be done without interference from either bail or chain hook.

Build the little furnace on a babbitting bench under the suspended pot. The furnace may be operated by compressed air or by some other form of airblast, as may be found convenient. Arrange a convenient hook in such position that when it is necessary to remove the

melting pot from above the furnace, the pot may be swung to one side and caught by the hook, thus holding the pot away from the furnace on the babbitting bench.

Sometimes, it is not possible to rig up an independent fire for heating the babbit-pot, and this must be done over the forge fire. In this case, do not suspend the melting pot over the forge. Hang it to one side, directly over the babbitting bench and locate a hook to support the pot when it is swung on its chain directly above the forge fire and at the proper height for being heated. Put the metal into the pot before swinging it to the forge fire and when heated, swing the pot away from the forge before touching the contents of the pot.

Indianapolis, Ind. JAMES F. HOBART.

Same Valve Setting for Condensing and Non-condensing Operation

SEVERAL YEARS ago I conducted some experiments which have led me to believe that there is no necessity to change the valve setting and adjustments when running an engine alternately condensing and non-condensing. These experiments dealt with two cross-compound Allis-Chalmers horizontal steam engines of 1500 hp. each. The engines were equipped with Corliss valve gears, and located in the old 3rd Avenue R. R. power station at 1st St. in Brooklyn, N. Y. I was chief engineer of the station at the time, and had the opportunity and privilege to try out several ideas that I held relating to steam engineering matters, one of which was doing away with compression in steam engine cylinder to an extent that was thought ruinous by my contemporaries.

Briefly, the story is this: The condensing water for these engines was obtained from the Gowanus canal, a dirty, greasy, acidulated body of water that prevented the maintenance of tight suction piping. The highest degree of vacuum we could obtain was 20 in. at high tide. At low tide we had to run non-condensing and then the trouble began. The low-pressure valves lifted from their seats due to compression, the valves having been set for running condensing, and slammed down again as the pressure in the cylinder gradually fell. Steam pressure in the boilers was maintained with difficulty and sometimes would drop from 140 lb. to 110 lb. during heavy load periods.

We reduced the compression in both engines, so that when running non-condensing, there was only a slight rounding at the corner of the indicator diagram; this stopped the slamming of the valves and no further trouble was experienced in maintaining 140 lb. pressure in the boilers. Then the question came up as to how the engines would behave when running condensing and with compression eliminated. We found that the engines ran equally well without compression, not only that, we secured quiet running and actually consumed less steam than before the change was made.

To sum up, we had reduced the compression to the least possible amount for both condensing and non-condensing operation, secured quiet running under both conditions and consumed less steam for some loads, over long periods of time.

My story relates to moderate speed engines (85 r.p.m.). I do not know whether or not my idea would work with short stroke high speed engines; but in any case I am quite sure that in most steam engines the compression pressure could profitably be cut down.

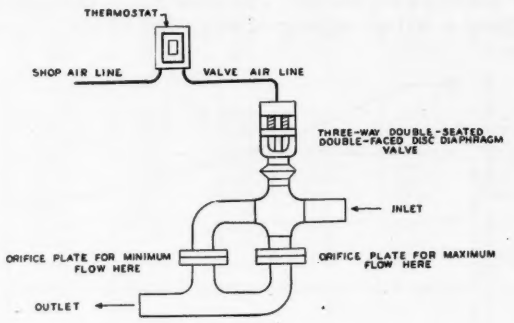
Brooklyn, N. Y. CHARLES J. MASON.

Heating System Control

AN IDEA for an inexpensive and simple heating system control to overcome the shortcomings of an on-and-off control is shown by the accompanying sketch. While I have not yet had an opportunity to put the idea in practice, I intend to do so soon. The equipment, I believe, is all manufactured at the present time although not in use in this combination. The idea may be applied to control an entire system, a group of radiators or a single radiator.

This means the control is flexible and may be turned into semi-automatic or non-automatic control at will. Control valve shown provides a maximum and minimum flow of steam through the same three-way double seated, double faced disc diaphram valve which by-passes the flow of steam through the upper port when the lower port is closed, one flow supplementing the other as called for by the room thermostat.

The key room thermostat, upon making and breaking contact, admits or relieves the diaphram of the valve of air which in turn seats one or the other of the disc facings for a maximum or minimum flow of steam controlled by metering orifices placed between the flanges.



SIMPLE HEATING CONTROL

Minimum flow may be that necessary to provide circulation in mild weather or that amount of steam that the system uses as an average. The maximum flow may be 20 per cent more than assigned maximum or an amount in excess of that ordinarily required for a quick pickup. Pipes should be installed as shown so that the maximum flow of steam will be available should the air supply fail.

Brooklyn, N. Y. WILLIAM ANDERSON.

Return Line Corrosion

IN YOUR JUNE 15th issue, the interesting article on "Return Line Corrosion" by Edward P. Schinman, fails to mention the corrosive effect of CO_2 (carbon dioxide) dissolved in the condensate.

He does state that "oxygen corrosion is accelerated in acid (low pH) solutions," but he does not state what might make the condensate acid. The answer is CO_2 generated in the boilers by the breaking down of the bicarbonates and carbonates in the feed water.

This CO_2 passes out of the boiler with the steam and part of it goes back into solution in the condensate, thus lowering the pH value.

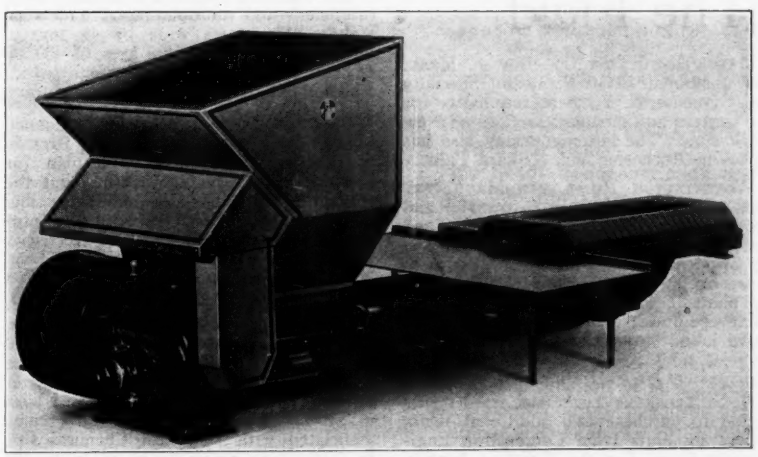
Treating the make-up water with lime will precipitate the bicarbonate hardness and thus reduce the amount of CO_2 that can be generated in the boilers.

New York, N. Y. WILLIAM J. RYAN.

New Equipment

Stokers for Low Pressure Service

THIS STOKER, made by Fairbanks, Morse & Co. of Chicago, is of underfeed type with motor-driven, worm-geared screw conveyor, feeding coal from the hopper into a cast-iron



retort in the fire box, the thrust of screw and shape of retort walls acting to distribute fuel in a uniform layer over the fire bed. Air is supplied under pressure by a fan through tuyeres in the retort.

These conditions produce a hot flame which permits burning low-grade coal, fuses the ash to clinkers and avoids smoke making. Control of fuel feed and air supply is provided according to the requirements of the installation. Sizes are available up to 1200 lb. coal an hour or boiler load of 250 hp.

Pipe Threader

THIS NEW 1-in. and 2-in. tool with 3-jaw holder adjusted by wing nuts has no bushings and is pro-

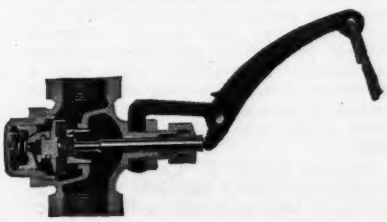
vided with a die head of new design. It is made either plain or with ratchet by Toledo Pipe Threading Machine Co., Toledo, Ohio.

Thru-Port Fluid Valve

THIS NEW valve design can be cleaned by running a rod through the line. It is turned from high quality carbon steel, with stem specially treated for high temperature service and renewable slip-on disc of stainless steel, free on the stem to prevent sticking. When wide open, the disc is entirely out of the fluid passageway. The relief passage permits escape of fluids caught under the plug as it closes. Body, bonnet, packing nut and gland are Parkerized against corrosion. It is made by Reading-Pratt & Cady Co., Inc.

Valve for Quick Opening and Closing

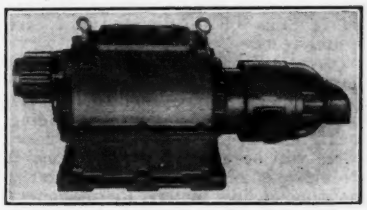
DESIGNED especially for use at bulk stations in loading trucks with gasoline or oil, this valve, manufactured by Jenkins Bros., 80 White St., New York, is opened by a slight



pull on the lever and is closed by spring and fluid pressure. This arrangement, with the guiding piston, avoids pounding in the line when flow is suddenly started or stopped, while the quick seating of the Jenkins removable disc gives close control of flow and prevents leakage. The yoke carrying the opening lever is adjustable to the most convenient position so that the valve can be located at the best point for operation in a vertical or a horizontal run of piping.

Motorized Speed Reducer

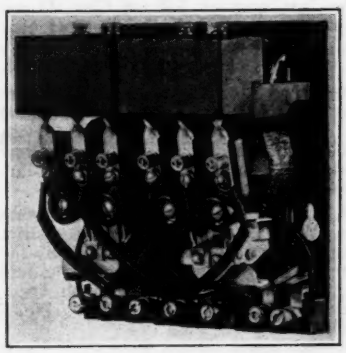
HERE ILLUSTRATED is a triple reduction unit with a speed ratio of 312.2 to 1, one of a lot made for driving sludge collectors at New York City's new sewage treatment plant on Ward Island. The motor shaft (which extends into the reducer housing) operates at 1165 r.p.m., and the low speed shaft at only 3.75 r.p.m. The motor with extended shaft, mounted in this manner, gives increased efficiency and compactness, reduces the floor



space required, and eliminates high-speed motor-shaft coupling. Roller bearings and continuous-tooth herringbone gears are used, running in oil. It is made by Link Belt Co., Philadelphia, Pa.

Reversing Magnetic Contactor

THREE POLE reversing magnetic contactor, interchangeable in rating and dimensions for a.c. and d.c. has been developed by the Industrial Controller Division, Square D Co., Milwaukee, Wis. Maximum rating 3 hp. The compact design, relatively small dimensions and convenient wiring arrangement make it particularly adaptable for hoists, window and door control, dumb waiters, reversing machine tools and similar applications.



Contactors have a positive mechanical interlock and magnetic safety latches to prevent accidental closing. Arranged for either two-wire or three-wire control. The edgewise mounting of the movable contacts and the form of arc suppressors are a new principle of design for increasing the arc rupturing capacity.

W. W. Tefft

MR. TEFFT, vice-president of the Fargo Engineering Co., died at Ann Arbor hospital, June 24 at the age of 50 yr., after several weeks' illness. He entered engineering as federal dredging inspector at Detroit in 1904, later going to Superior, Wis., in charge of construction of a large hydroelectric plant. Returning to Michigan to take charge of power dams on Manistee River, he joined Fargo Engineering Co. in 1911, having in charge for 10 yr. many important projects. In 1922 he became vice-president of Consumers Power Co. and in 1924 chief engineer for Commonwealth Power in charge of work for 8 companies. He was in this work until 1928, when he resigned to take up consulting work with Fargo Engineering Co.

Mr. Tefft was interested in civic and community welfare, being president of the Methodist Foundation of Michigan, member of American Committee of the World Power Conference, honorary member of Albion College Alumni Assn., director of Union and Peoples National bank and a member of several clubs in Jackson, Mich., where he resided.

News From The Field

ON THE NORTHEAST corner of Eighth Street and Broadway, Cincinnati, Ohio, the new Cincinnati Times-Star Building is nearing completion. It will house the offices and printing plant of the paper. The entire building, with land, building and equipment, represents an investment of about $4,000,000; the building proper about $2,250,000. Samuel Hannaford & Sons of Cincinnati, Ohio, are the architects.

Three 2427 sq. ft. Tudor fire tube boilers fired by Detroit stokers will be installed. These three boilers will be served by one steel chimney extending 261 ft. above the boiler room floor. Boilers will be equipped with Diamond soot blowers and Brown boiler panels, consisting of flow meters, thermometers and CO_2 recorders.

Dunham differential heating system will be used with American direct radiators, Rome concealed radiators and Johnson temperature control. The reel room, press room and paper storage will be supplied with washed air by Bishop and Babcock spray washers. William Powell valves and fittings will be used throughout, with all exposed supply piping over 4 in. consisting of The National Tube Co.'s steel piping. All boiler piping will be welded.

NORMAN W. FOY has been appointed sales manager for Republic Steel Corp. in the Chicago district with headquarters in the McCormick Bldg, Chicago.

HENRY C. MILLER has been appointed sales manager of the Power Plant Equipment Division of The Swartwout Co., Cleveland, Ohio. He has had twelve years experience in connection with the design, manufacturing, selling, and servicing of the complete line of equipment.

POTOMAC ELECTRIC Power Co., has completed negotiations for inter-connection of its system with high-tension lines of the Safe Harbor-Baltimore system at a point just west of Ellicott City, 23 mi. from Washington. It is expected that work will begin soon and that interchange of power will be started by October, 1933.

ASSOCIATION of Consulting Management Engineers has appointed Nathaniel W. Barnes as executive secretary, with offices at Room 1425, 122 E. 42nd St., New York City, a joint arrangement with Marketing Associates, Inc.

R. F. BALDWIN, for 10 yr. with Irving Iron Wks., has been appointed district sales manager by Hendrick Mfg. Co., for eastern Pennsylvania, southern New Jersey, Delaware and Virginia, with headquarters at 5813 N. Fairhill St., Philadelphia, Pa.

MASON REGULATOR Co., Boston, Mass., has appointed O'Brien Steam Specialty Co., Syracuse, N. Y., as representative for the western and northern sections of New York state. The latter company also has offices in Rochester and Niagara Falls.

WORTHINGTON PUMP AND MACHINERY CORP., Harrison, N. J., is to transfer and consolidate the designing, engineering and manufacturing activities formerly carried on at its Cincinnati, Ohio, Works with those of its Buffalo, N. Y., manufacturing plant. For the present, the Cincinnati plant equipment will remain intact, this move in no way affecting the Cincinnati District sales office which is under the management of Earl Vinnedge.

U. S. TREASURY DEPT. has acted on its option to purchase two additional steam generating units from Combustion Engineering Corp. for the Triangle heating plant. These are for 400 lbs., for continuous production of 215,000 lbs. steam an hour, with maximum of 237,000 lbs. an hour from and at 212 deg. F. Each unit includes boiler, steel cased setting, water-cooled furnace, forced and induced draft equipment and multiple retort underfeed stokers, 15 retorts wide by 45 tuyeres long with projected grate area of 480 sq. ft. United Engineers & Constructors, Inc., Philadelphia are the consulting engineers.

NATIONAL ELECTRIC Cookery Council under leadership of its chairman, Preston S. Arkwright, has adopted a plan for councils to be organized throughout the country with plan book, newspaper mat service and divisional directors to promote the greater acceptance of electricity for cooking. Details can be had from N.E.L.A. headquarters, 420 Lexington Ave., New York City.

JAMES WILLIAMS HARKINS, for 33 yr. associated with the Dearborn Chemical Co., Chicago, passed away at his home in Oak Park, Illinois, on July 12th, after an illness of some months. He was born in St. Louis, May 25, 1870, and became associated with Dearborn Chemical Co., in 1900. For many years prior to his death Mr. Harkins had been in charge of Chicago sales. He was a member of several engineering societies and had many friends among engineers throughout the country.

For the Engineer's Library

Ross refrigerating units are fully described and illustrated in Bulletin 325, an 8-p. circular issued by Ross Heater & Mfg. Co., Inc., Buffalo, N. Y. Ratings are from 5 to 1000 t. per 24 hr. The principle is vacuum evaporation to produce chilled water at 35 to 70 deg. F.

DINGS MAGNETIC SEPARATOR Co., Milwaukee, is sending out a 16-p. bulletin on the installation and use of magnetic clutches for special and general power transmission applications, containing a number of installation diagrams and the method of calculating the required horsepower rating, also tables of performance data.

READING-PRATT & CADY Co., INC., Bridgeport, Conn., has just issued an eight page catalog describing its bar stock valves in globe, angle, and cross patterns of bronze, carbon steel, and stainless steel.

CAST-REFRACT, a material for casting special refractory shapes in forms on the job is described in a circular issued by Quigley Co., Inc., 56 W. 45th St., New York City.

MULTI-SPEED squirrel-cage motors is the subject of a bulletin released by the Wagner Electric Corp., 6400 Plymouth Ave., St. Louis, Mo. Illustrated with installation photographs, each installation is completely described as to problems involved and the type of motor meeting them, covering constant-torque, constant-horsepower and variable-torque motors, further classified as two-speed, three-speed and four-speed. It is known as Bulletin 174, Part 5, Pages 13 to 18.

EXPANSION JOINTS, a new illustrated bulletin of 8 p., describes in detail the FlexoDisc packless expansion joint for special expansion problems, in sizes from 3 to 30 in. with expansion element of alloy steel. Croll-Reynolds Engineering Co., Inc., 17 John Street, New York, N. Y.

UNION Universal boilers are exemplified in a 16-p. bulletin giving illustrations, dimensions and construction, issued by Union Iron Works, Erie, Pa.

CHRONOFLO electric fluid meter is announced by Builders Iron Foundry, Providence, R. I., and described in a 12-p. bulletin No. 261, which explains the principle of action and illustrates various applications for use with venturi tubes or orifices.

UNIONS with bronze to bronze joints are described in a folder issued by E. M. Dart Mfg. Co., Providence, R. I.

SARCO PIPE SAVERS for insertion in the threaded ends of pipe to prolong pipe run life are described in a circular from Sarco Co., Inc., 183 Madison Ave., New York City.